Chapter 3

Steve Hillebrand/USFWS

Great blue heron

Existing Environment

- Introduction
- Water Quality and Health of the Great Bay Estuary
- Conserved Lands Network
- Land Use Trends
- Climate
- Part I. The Regional Setting
  - Air Quality
  - The Historical Picture
  - Regional Demographics and Economic Setting
- Part II. The Refuge and its Resources
  - Refuge Administration
  - Refuge Natural Resources
  - Cultural and Historic Resources
  - Public Use Programs
  - Volunteer Program
  - Key Refuge Partnerships
  - Karner Blue Butterfly Conservation Easement

Introduction

This chapter describes the ecological, physical, and socioeconomic setting of Great Bay Refuge in a regional and local context. We first describe the regional landscape, including its historical and contemporary influences. We then describe the refuge and its resources.

Part I. The Regional Setting

In addition to the 1,103-acre Great Bay Refuge, we also administer the 29-acre conservation easement in Concord, New Hampshire, and manage it as pine barrens habitat for the federally endangered Karner blue butterfly. The conservation easement is approximately 45 miles west of Great Bay and is described separately below.

Great Bay Refuge lies within the Gulf of Maine watershed, an immense area extending from eastern Quebec, Canada, to Cape Cod in Massachusetts. Along New Hampshire's coast, the Gulf of Maine's tidal waters flow twice daily up the Piscataqua River through Little Bay and then into Great Bay at Furber Strait. Collectively, these water bodies are described as the Great Bay Estuary system. This is one of the most productive ecosystems on the East Coast (Odell et al. 2006). The refuge sits on the eastern shore of Great Bay.

The Great Bay Estuary is approximately 10 miles inland from New Hampshire's seacoast and adds more than 130 miles of tidal shoreline to the 18 miles of shoreline along the State's coast. Seven major rivers flow into the Great Bay Estuary system: the Winnicut, Squamscot, Lamprey, Oyster, Bellamy, Cocheco, and Salmon Falls. Together these rivers drain nearly 1,000 square miles. The major habitats in Great Bay are eelgrass meadows, mudflats, salt marsh, channel bottoms, and rocky intertidal habitat. These habitats support over 160 bird, fish, and plant species, 26 of which are State-listed threatened or endangered (see appendix A) (*http://greatbay.org/about/index.htm;* accessed May 2011*)*. Birders from all over the world come to view migratory birds on Great Bay (NHEP 2000). Great Bay Estuary also provides numerous fishing and shellfishing opportunities, such as recreational oyster and clam harvesting; recreational fishing for striped bass, bluefish, alewife, and blueback herring; commercial and recreational lobstering; and commercial trapping of American eels for bait and for export.

Great Bay Refuge is located on a portion of the former Pease Air Force Base. The rest of the former base is now Pease International Tradeport (Tradeport). The approximately 3,000-acre Tradeport has office and industrial spaces, an active airport, restaurants, hotels, and other amenities. Past land uses, including farming and 30 years of use as an Air Force Base, dramatically changed the upland plant community from an Appalachian oak-pine forest to a mix of transitional pine-hardwood forest, shrubs, fields, and impounded waters. Only some remnants of the historical forest community remain in the area.

Storage bunker in former Weapons Storage Area

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Water Quality and Health of the Great Bay Estuary

Several centers of ecological research and management in the area provide a detailed picture of the historical and current health of the Great Bay Estuary and watershed. These centers, described in more detail in chapter 1, include PREP, GBNERR, and NHCP, among others.

In an overview on the restoration of the Great Bay Estuary, Odell et al. (2006) summarized the condition of the estuary system as follows:

> "A close look at the history and current condition of the Great Bay estuarine system reveals that although it is relatively intact and remarkably resilient, it has been significantly altered and degraded. Prior to 1900, all of the rivers and many of the tributaries were dammed, extensive logging throughout the watershed brought tons of silt into tidal rivers, the bay bottom was covered in sawdust up to a foot deep and poisoned with industrial wastes, and aquatic resources were over harvested. Since that time, significant human population growth and development throughout the Great Bay watershed have created new stresses—notably habitat loss, and new levels and types of point and non-point source pollution."

A concerted effort to understand, protect, and restore the Great Bay Estuary is underway among many local, State, and Federal partners. Particular emphasis is placed on land protection, controlling discharges from wastewater treatment plants and other pollution sources, and using best management practices to minimize impacts from development and resource extraction (Odell at al. 2006).

Every 3 years, PREP compiles a report on the "State of the Estuaries." The report tracks trends in 12 environmental indicators to assess the health of New Hampshire's estuaries. The report describes each indicator as having an either positive, negative, or cautionary trend. A cautionary trend is a trend that demonstrates possibly deteriorating conditions, but more information is needed to fully assess the indicator. In the 2009 report, 11 out of the 12 indicators showed either negative or cautionary trends for Great Bay (table 3.1). In the previous 2006 report, only 7 out of the 12 indicators had either negative or cautionary trends. The report recognizes that although there have been many successful projects to conserve land or restore habitat around Great Bay, these projects have not been able to keep up with continued habitat loss and human development (PREP 2009).

Table 3.1. Environmental Indicator Trends in the Great Bay Estuary (PREP 2009).

Indicator	Situation	Trend*
Dry weather bacteria concentrations	Concentrations in Great Bay decreased significantly in the 1990s, but no change in last 10 years.	!
Toxic contaminants in shellfish	Concentrations of a petroleum product have increased by 218 percent in the Piscataqua River over past 16 years.	!
Toxic contaminants in sediments	Toxic contaminants found in 24 percent of estuarine sediment.	!
Nitrogen in Great Bay	Dissolved inorganic nitrogen concentrations increased in Great Bay by 44 percent in past 25 years; the total nitrogen load to Great Bay increased 42 percent in past 5 years.	–
Dissolved oxygen	Levels fall below State standards often in tidal rivers, rarely in the bay.	!
Oysters	Number of adult oysters in Great Bay declined by 95 percent in the 1990s; the population has increased slowly since 2000.	–

Indicator	Situation	Trend*
Eelgrass	Eelgrass cover in Great Bay has declined by 37 percent between 1990 and 2008 and completely disappeared from the tidal rivers, Little Bay, and the Piscataqua River.	–
Anadromous fish	Returning anadromous fish are limited by various factors including water quality, passage around dams, and flooding.	!
Habitat restoration	Yes for salt marsh, but oyster and eelgrass habitats have been restored at a slower rate.	!
Impervious surfaces	In 2005, 7.5 percent of the land area of the watershed was covered by impervious surfaces, and 9 subwatersheds had greater than 10 percent impervious cover. In 2005, the town of Newington, NH had 20.2 percent imperviousness; up from 13.2 percent in 1990.	–
Land conservation	At the end of 2008, 76,269 acres in the Piscataqua watershed are protected, which amounted to 11.3 percent of the land area.	+

** + is a positive trend; - is a negative trend; ! is a cautionary trend.*

Conserved Lands Network

Great Bay Refuge is within the boundaries of GBNERR (map 3.1). The reserve was designated in 1989, encompassing 4,500 acres of tidal waters and wetlands and 3,000 acres of surrounding upland. The refuge and the reserve are part of the Great Bay Resource Protection Partnership (GBRPP), a coalition working to permanently protect land in 24 towns around Great Bay, including those within the boundaries of the reserve (map 1.1). The partnership funded the protection of 5,098 acres in the Great Bay region from 1996 to 2008, and an additional 3,052 acres were protected as a match to the partnership-funded lands (*http://www.greatbaypartnership.org/index.html; a*ccessed May 2011*)*.

Great Bay Refuge is the largest block of protected land on Great Bay. Table 3.2 lists other key conserved lands around the Great Bay Estuary.

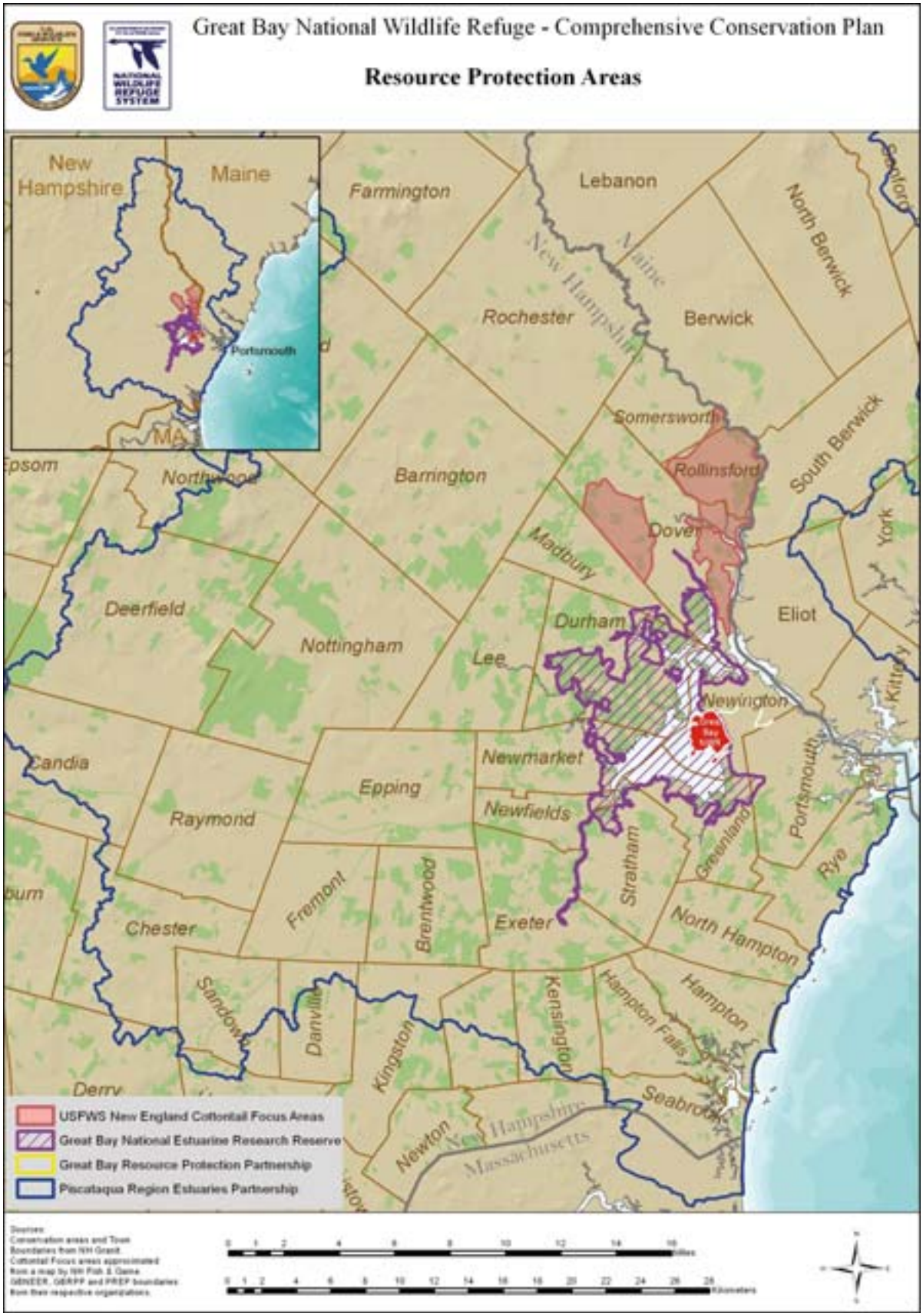
Table 3.2. Conservation Lands Bordering Great Bay Estuary

Name	Town	Acres	Ownership
Great Bay National Wildlife Refuge	Newington	1,103	U.S. Fish and Wildlife Service
Fox Point	Newington	119	Town of Newington
Wagon Hill Farm	Durham	130	Town of Durham
Adams Point	Durham	70	NH Fish and Game
Wilcox Point	Durham	38	NH Fish and Game
Lubberland Creek	Newmarket	70	The Nature Conservancy
Shackford Point	Newmarket	34	NH Fish and Game
Sandy Point (Great Bay Discovery Center)	Greenland	46	NH Fish and Game
Great Bay Wildlife Management Area	Greenland	32	NH Fish and Game

Land Use Trends

Despite the network of conservation lands in the Great Bay watershed, future growth is a concern, especially in the northern portion of the watershed on those lands not protected. As the population of the region increases, there is an associated increase in sources of pollution. Developed lands also reduce or fragment wildlife habitat. Development creates more impervious surfaces, such as paved roads, parking lots, and buildings. Impervious surfaces increase the volume

Map 3.1. Resource Protection Areas



Osprey

Matt Poole/USFWS

and velocity of stormwater runoff and the sediment and pollutant load flowing into the estuary. Because of this, the amount of impervious surface in a watershed is a good indicator of stream and water quality (PREP 2009). Generally, water quality deterioration is expected in watersheds with greater than 10 percent impervious surface. According to PREP, 7.5 percent of the land area of the Piscataqua watershed was covered with impervious surface in 2005. Impervious surfaces continue to be added to the watershed at a rate of approximately 1,500 acres a year (PREP 2009). The town of Newington, where the refuge is located, has one of the highest levels of impervious surfaces in the watershed; increasing from 18 percent in 2000 to over 20 percent in 2005 (PREP 2009).

Climate

Along the coastal lowlands, winter temperatures average about 30°F and summer temperatures average about 80°F. At higher elevations and further inland, winter temperatures are often 10 to 12°F cooler. Afternoon sea breezes affect the refuge in spring and summer, with noticeable wind shifts at about 11 a.m. and again just before sunset. Further inland, low elevation areas can be 5 to 10°F warmer during summer, but cooler as elevation rises. Annual precipitation is uniform throughout the year with the wettest month being November (greater than 5 inches on average). Total annual precipitation Statewide is about 45 inches. Annual snowfall for coastal areas is 50 inches and higher, inland elevations can receive 150 inches. Much of the precipitation is the result of cooler air from the polar region meeting a warmer, moist southerly air mass riding the Atlantic seaboard northward (Schroeder 1970). The resulting storms can be quite severe and can occur year-round.

Air Quality

The Clean Air Act of 1963 (P.L. 88-206), as amended, requires EPA to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards: primary and secondary standards. Primary standards set limits to protect public health, including the health of sensitive populations such as people with asthma, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, and damage to animals, crops, vegetation, and buildings (*http://www.airmap.sr.unh.edu/background/naaqs2.html;* accessed May 2011).

The EPA has also developed an Air Quality Index (AQI) that incorporates their standards for carbon monoxide, nitrogen dioxide, ozone, particulates, and sulfur dioxide. The AQI is used to measure the severity of air quality impacts to human health. Table 3.3 provides a summary of AQI values for in Rockingham County, New Hampshire, from 2001 to 2011. Below we provide more detailed information on regional air quality issues and sources of air pollution.

Table 3.3. Air Quality Index Values for Rockingham County, New Hampshire, 2001 to 2011.

Years	Number of Days when Air Quality was...				
	Good	Moderate	Unsafe for Sentive Groups	Unhealthy	Very Unhealthy
2001	311	36	16	2	-
2002	267	70	25	3	-
2003	394	62	9	-	-
2004	311	50	4	1	-
2005	309	50	6	-	-
2006	310	47	8	-	-
2007	323	33	8	1	-
2008	331	31	4	-	-
2009	342	21	2	-	-
2010	328	34	3	-	-
2011	314	49	2	-	-
2011	314	49	2	-	-

Source: EPA 2012 (http://www.epa.gov/airdata/ad_rep_aqi.html; accessed May 2012).

Regional Air Quality Issues and Sources of Air Pollution

Between 2001 and 2011, the main air pollutants in Rockingham County, New Hampshire were ozone, nitrogen dioxide, sulfur dioxide, and particulate matter. Of these four pollutants, regional ozone levels most frequently exceed EPA standards. Ozone at ground-level is a pollutant that forms in the atmosphere as a by-product caused by the release of volatile organic compounds and nitrogen oxides emitted from automobiles, diesel trucks, and industrial sources. It can lead to a variety of human health concerns, including chest pain, coughing, throat irritation, and can reduce lung function. It can also worsen asthma, emphysema, and bronchitis (EPA 2009). During the summer, most of southern New Hampshire and coastal Maine experiences ozone events that are considered very unhealthy for humans and the environment. These very high ozone levels are caused by a combination of factors (e.g., dense population, local pollution sources, and being downwind of sources outside the region). On average, southern New Hampshire and coastal Maine experience 3 to 5 days per year of very unhealthy ozone levels, with some years (e.g., 1988) that are much worse. The Dover-Portsmouth-Rochester, New Hampshire region is also designated as "serious non-attainment zones" because the region often exceeds the air quality standards for ozone set by the EPA.

The sources of these pollutants and other air quality issues in the region are largely the result of the influx of airborne pollutants originating from industrial regions, metropolitan centers, and transportation corridors located upwind, and primarily from the Midwest and Mid-Atlantic regions. Many unknowns still exist about air quality in New England, including the specific sources of pollution, and effects of weather patterns and climate changes (Wake et al. 2004). However, industrial and transportation sources within New England also contribute to air quality issues (Wake et al. 2004). The New Hampshire seacoast, including the town of Newington, is heavily commercialized and local sources of air quality issues include industrial, commercial, and transportation sources such as the National Gypsum plant, which manufactures gypsum wall boards, in Portsmouth, New Hampshire, the Public Service of New Hampshire (PSNH) Schiller Station, which operates three coal and wood-burning steam boilers, in Newington, New Hampshire, and emissions from heavy automobile traffic.

The Historical Picture

After the Ice Age

New England emerged from an ice age 12,000 years ago. A 1-mile thick glacier scraped and molded the valleys, slopes, and mountain tops, leaving behind a landscape bare of vegetation. At the southern edge of the glacier, however, plants survived and immediately began to recolonize the newly exposed soils (Marchand 1987). Large mammals, including mastodons, wandered the spruce parkland and grassy savanna, but disappeared quickly at the same time the glacier receded and humans advanced across the region.

Continual weathering and erosion of rock over time released nutrients and created new soils for plants to grow. Hardwood and softwood tree species advanced independently of one another creating different forest communities through time (Davis 1983). The sequence of plant species' arrivals as the glacier receded was also different at different sites (Davis 1981). In a relatively short time period (about 2,000 years), the land cover changed from tundra to woodland with scattered trees, and then to closed canopy forest. Pine and oak arrived around 11,500 years ago with a warmer and drier climate. Eastern hemlock became more prevalent around 10,000 years ago with a wetter climate (Manomet Center 2010). Graham (1992) reported similar species-specific responses by mammals to post-glacier climate changes.

Native People

Prior to European arrival, coastal southern New England likely supported a "shifting mosaic" of open land habitat within a mostly forested landscape. The open lands were a result of native heathlands, grasslands and shrublands, extensive beaver meadows, periodic fires, shifting agriculture by Native Americans, and occasional hurricanes (Cronin 1983, DeGraaf and Yamasaki 2001). DeGraaf and Yamasaki (2001) and Askins (2000) reported broad evidence for the presence of extensive grasslands along the coast and major rivers in pre-European New England, although not all of these open areas are attributed to Native American influences.

Native Americans in southern New England fished and shellfished for much of their food, as well as hunting birds and trapping and hunting small game. When colonists landed on Massachusetts shores in the early 1600s, they saw large clearings and open woodlands. Waterfowl, deer, ruffed grouse, wild turkey, and wild pigeons were abundant (Marchand 1987, Foss 1992, DeGraaf and Yamasaki 2001). Colonists found old growth forests not far inland, including old stands of mixed hardwoods, white pine, and hemlock at low elevations, and spruce and fir in the mountains (Marchand 1987).

European Settlement

European contact (e.g., explorers and traders) with native people began during the 16th century in New England. Foster and Motzkin (2003) suggested that European arrival prompted such rapid and profound changes to the lifestyle and land use practices of indigenous people that by the time colonists began to settle here, the landscape was already altered. Foster and Motzkin (2003) suggested that expansive clearing for agriculture and semi-permanent (rather than mobile) villages were a new phenomenon and resulted from European influence.

European colonists brought new land use concepts such as permanent settlements and political boundaries. They shifted land use from primarily subsistence farming and gathering to harvesting and export of natural resources (Foss 1992). Just 100 years after the colonists arrived, the forests were rapidly being logged. By 1830, central New England was 80 percent cleared (Marchand 1987).

However, shortly after this, many people began leaving the rough, rocky New England landscape for other opportunities. The abandonment was due to a variety of factors, including the California Gold Rush, the Industrial Revolution, new railroads, richer Midwestern soils, and the Civil War. Abandoned farm fields began reverting back to forest. White pine seeded into the fields and pastures

and by 1900 was ready for harvest. An understory of hardwoods, released from the shade of white pine, emerged as the new dominant vegetation. This is a legacy that remains today (Marchand 1987, DeGraaf and Yamasaki 2001).

The Great Bay Estuary was long a center of commerce for natural resource based industries including fishing and logging. Early settlers exploited the region's extensive forests and abundant populations of salmon, shad, sturgeon, alewife, blueback herring, and shellfish. Flat-bottomed gundalows, a type of sailing barge, were used to transport cargo up and down the swift-current and shallow waters of the Piscataqua River to and from the towns on Little Bay and Great Bay. Shoe and textile mills were built on the water's edge of the towns within the estuary (Jones 2000). By 1790, Portsmouth, New Hampshire was the 14th largest city in the country, known for its shipping and fishing industries (Bolster 2002). Growing human populations, accompanied by unchecked sewage disposal and dumping of industrial wastes degraded the water quality in the estuary, led to population declines of fish and shellfish. Beginning in the 1940s, pollution controls began to improve water quality and habitats in Great Bay (Jones 2000).

Climatic Effects and Natural and Human Disturbances

The Northeastern U.S. is particularly cold, given its latitude (Marchand 1987). The reason for the region's cold climate is partly a result of the pattern of atmospheric circulation in this hemisphere. Low pressure systems all converge on New England, regardless of their origin, and pull cold Canadian air in behind as they pass over the Northeast (Marchand, 1987). New England weather conditions are influenced more by the North American landmass than by the Atlantic Ocean except along the coastline (Taylor et al. 1996). Forty to forty-five inches of precipitation fall about evenly throughout the year, although drought periods occur in some years (Patterson and Sassaman 1988).

Natural disturbances vary across New England, depending on geographic location, forest type, and local conditions. In presettlement times, coastal regions experienced the highest rates of disturbance because of the prevalence of fire-dependent sandy pine-oak barrens, higher densities of Native Americans, higher frequencies of hurricanes, and longer snow-free periods. These disturbance regimes may have maintained about 1 to 3 percent of the inland northern hardwoods forests and greater than 10 percent of the coastal pine-oak barrens, in early successional habitat (Lorimer and White 2003).

Native insects and disease, ice storms, droughts, and floods have caused both minor and major disturbances. Lorimer and White (2003) depicted hurricane frequencies as varying from 85 years in southeastern New England, 150 years through central Massachusetts and the southeast corner of New Hampshire, to 380 years or more in northern New England. Lorimer (1977) estimated catastrophic disturbances from fire and wind at intervals of 800 and 1,150 years, respectively.

Agriculture, logging, fire, wind, exotic pests and diseases, and development have significantly altered the New England landscape. Agriculture had the greatest effect on New England's forests, causing major changes in cover types and soils over a vast area. Although most of the region's forests were cut at least once, most logging did not affect succession or impact soils (DeGraaf and Yamasaki 2001). Human settlements are emerging as the major cause of permanent habitat loss compared to previous impacts from agriculture and logging.

Climate Change

Climate changes are predicted to affect climate patterns over time (Lorimer 2001). The greatest effects of climate change will be on regional air and water temperatures, precipitation patterns, storm intensity, and sea levels. In the Northeastern United States, the average air temperature is expected to rise by

8°F by 2100, with the greatest increase during winter months (Frumhoff et al. 2007). New Hampshire's summers are anticipated to be similar to those currently experienced in Virginia (Frumhoff et al. 2007). Climate change is anticipated to influence natural disturbances patterns and result in a decrease in freeze periods, decreased snow cover, increased storm intensities and frequencies, increased intensity and frequency of summer droughts, damaging ozone, and an increase in the spread of invasive species and disease (NHFG 2005, Manomet Center 2010). The resulting effects on wildlife and habitats are expected to be variable and species-specific, with a predicted general trend of ranges shifting northward by 350 to 500 miles (Frumhoff et al. 2007).

Tidal marshes are among the most susceptible ecosystems to climate change, especially rapid sea level rise. In an effort to address these potential effects on national wildlife refuges, the Service ran Sea Levels Affecting Marshes Model (SLAMM) 5.0 analyses to estimate the impacts of sea level rise for all coastal refuges, including Great Bay Refuge. The model predicted that the salt marshes at Great Bay Refuge would be resilient to the effects of sea level rise, with very little conversion of uplands to wetland habitat (Clough and Larson 2009). The majority of the refuge is dominated by oak-hickory forest, which is at the northern edge of its range. Under climate change scenarios, this forest type is expected to persist and expand northwards. Increasing summer droughts and disease is expected to increase the likelihood of forest fires, which the oak-hickory habitat is adapted to. Two habitats on the refuge that are vulnerable to climate change are hemlock communities and forested wetlands. The hemlock woolly adelgid, an invasive pest, is currently at the northern edge of its range in southern New Hampshire, and is expected to expand northwards with increasing winter temperatures. Earlier flooding and prolonged summer drought may result in a reduction of forested wetlands on the refuge and decrease both the quantity and quality of these habitats for wetland-dependent species, such as northern leopard frog and willow flycatcher. The main guiding principal of the Service's climate change adaptation planning is to maintain or increase resiliency of the refuge's habitats and ecological process. The uncertainty about the future effects of climate change also requires refuge managers to use adaptive management to maintain healthy ecosystems in light of the unpredictability (Inkley et al. 2004).

Opossum

Tim Williams.

Wildlife Changes

Wildlife populations ebb and flow as habitat conditions vary in space and time. Natural and human disturbances intervene, shifting species abundance and diversity. Some species, such as alpine plants, have been here for 10,000 years or more. Others, like the coyote, arrived in the last 75 years. Change is inevitable and natural, although human activities in the last 400 years have significantly altered the landscape compared to the previous 10,000 years when humans first colonized the northeast (Foss 1992).

During the 1800s, many wildlife species declined because of habitat loss (e.g., forest clearing), bounty and market hunting, millinery trade (for feathers to use in hats), and natural history specimen collecting (Foster et al. 2002). The millinery trade in the late 1800s, and hunting and egg collecting (for food and bait) decimated Arctic, common, and roseate tern populations in the Gulf of Maine (Drury 1973). Mountain lion, gray wolf, elk, and caribou were extirpated from the area by the mid-1800s or early 1900s and have not recolonized the region. Heath hen, passenger pigeon, great auk, Labrador duck, and sea mink became extinct at the hand of humans during the same period (DeGraaf and Yamasaki 2001, Foster et al. 2002).

The historical record is unclear on the abundance and distribution of open land plant and animal species in the Northeast prior to European settlement (Foster and Motzkin 2003). Scattered large grasslands occurred in coastal areas including the approximately 59,300-acre Hempstead Plain on Long Island and the blueberry barrens along the Maine coast (Askins 1997, Winne 1997). Smaller, more temporary grasslands were created when beavers abandoned their dams, or by fires set by lightning or humans (Askins 1997). Some grassland bird species, such as horned lark and dickcissel, likely spread eastward from the Midwest as lands here were cleared for agriculture. However, some grassland birds, including bobolink, eastern meadowlark, and upland sandpiper, may have existed here long before European settlement in these coastal barrens, heathlands, and grasslands (Askins 1997). Populations of grassland birds have declined significantly across their range in the last 40 years (Askins 1997, Norment 2002). After farm abandonment escalated in the early 1900s, wildlife species that prefer thickets, brush lands, and young forests increased (Litvaitis 2003).

The young hardwood forests that emerged in the 1920s and 1930s provided premier habitat for ruffed grouse (DeGraaf and Yamasaki 2001). The succession of that forest into mature hardwood forests in the late 1900s caused a decline in the grouse population but an increase in other species that prefer more mature forests. Abundances of early successional species declined to levels approaching presettlement levels (Litvaitis 2003).

Eastern coyotes were first sighted in New Hampshire and Vermont in the 1940s, in northern Maine in the 1930s, and in Massachusetts in the 1950s. DeGraaf and Yamasaki (2001) reported three major trends in New England's wildlife: forest species are increasing (e.g., American black bear, beaver, deer, wild turkey, pileated woodpecker), grassland and shrubland species are declining (e.g., grasshopper sparrow, bobolink, upland sandpiper, whip-poor-will), and many southern species are expanding their ranges northward (e.g., glossy ibis, willet, Carolina wren, northern cardinal, northern mockingbird, Virginia opossum). A few species, such as common raven, fisher, and moose are expanding southward. A group of species remains regionally extirpated, including wolverine and mountain lion, although Canada lynx have returned to northern Maine and New Hampshire (DeGraaf and Yamasaki 2001).

Regional Demographics and Economic Setting

Population and Demographics

Great Bay Refuge is located in southern New Hampshire in the town of Newington in Rockingham County. Its close proximity to metropolitan areas, including Boston, Massachusetts, and Manchester, New Hampshire, expose the refuge to the effects of urban sprawl. As real estate in cities and their outskirts becomes scarce and more expensive, city residents look outward for more affordable housing. In addition, New Hampshire offers numerous scenic and natural areas, and opportunities for outdoor recreation.

An analysis of population data by the New Hampshire Office of Energy and Planning (NHOEP) shows the State divided into the slow-growing north and the fast-growing south. Since 1960, New Hampshire's population has increased by about 703,000 people. More than 60 percent of that growth occurred in Rockingham and Hillsborough Counties. This growth is expected to shift away from Rockingham County because of the decreasing availability and increasing cost of land, and the greater freedom to reside in and commute from more remote

communities. In contrast, Merrimack County is expected to gain in the State's future share of growth (NHOEP 2006).

Rockingham County's 695 square miles of land area contained 426 persons per square mile in 2007. The estimated 2007 population of Rockingham County is 296,543, an increase of 19,184 people since 2000. Rockingham County was the second most populated county in the State in 2007, accounting for about 23 percent of New Hampshire's total population. From 2005 to 2007, the median age in Rockingham County was 40.2 years. Persons under 18 years accounted for 24 percent of the population, while 11 percent were 65 years or older (USDOC 2007). Table 3.4 presents the population trends for Rockingham County and the communities surrounding the refuge.

Table 3.4. Population Trends for Communities and the County Around Great Bay Refuge.

	Population in 2010			Percent Population Change	Projected Population
	Residents	Persons per Square Mile	Median Age	2000-2010	2020
New Hampshire	1,316,170	147.0	41.1	+6.5	1,470,010
Rockingham County, NH	295,223	424.8	42.3	+6.4	331,190
Newington, NH	753	94.1	48.0	-2.8	900
Greenland, NH	3,349	334.9	43.8	+4.4	3,880
Portsmouth, NH	20,779	1,298.7	40.3	-0.02	22,730

Source: U.S. Census Bureau (2010) and New Hampshire Office of Energy and Planning (projections compiled Jan 2007 based on past trends).

Environmental Justice

Executive Order #12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations," (dated February 11, 1994) requires Federal agencies to identify and address any potential disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Presidential Memorandum accompanying this order further directs Federal agencies to improve opportunities for community input and the accessibility of meetings, documents, and notices (CEQ 1997). To facilitate this, Federal agencies should also consider if a significant portion of the affected community is linguistically isolated, and as warranted, provide translated documents and other appropriate outreach materials.

In creating table 3.5 below, we used the following definitions:

- **Minority population** includes persons who are members of the following groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.
- **Low-income population** includes persons living below the poverty line.
- **Linguistically isolated population** includes persons who speak English less than "very well."

Table 3.5. Regional Environmental Justice Characteristics.

	Rockingham County, NH	Town of Newington, NH
Minority Population (as percent of total population)	6.2 percent	5.8 percent
Low-income Population (as percent of total population)	5.0 percent	6.8 percent
Linguistically Isolated Population (as percent of total population)	1.8 percent	3.4 percent

Source: U.S. Census Bureau (2010).

Business and Economic Climate

New Hampshire has made several economic transitions in the past. Historically, the area was agriculturally based. The economy later shifted to textile and leather goods manufacturing during the Industrial Era and then shifted again to the manufacturing of higher valued goods such as fabricated metal and electrical goods. Currently, the State is in transition to a post-manufacturing, service-based economy (NHOEP 2006).

New Hampshire has a 70 percent "labor force participation rate." This means that 70 percent of the population age 16 and older is either employed or unemployed but able to work and looking for a job. In 2007, retail was the largest employing industry in the State, providing jobs for 97,700 workers (NHES 2009). New Hampshire does not tax personal income, sales, inventory, capital gains, personal property, machinery, or equipment. This contributes to its competitive status in the retail industry. In 2007, the State median income was $67,576 (NHES 2009).

In 2007, 38 percent of the workforce in Rockingham County was employed in management, professional, and related occupations, while 27 percent filled sales and office occupations. The remaining workforce was divided among service occupations including production, transportation, and material moving; and construction, extraction, maintenance and repair occupations. The primary industries in the county are educational services, health care, and social assistance, and retail. The Great Bay Estuary is important to local and regional recreational and commercial fisheries (Jones 2000). In 2007, the median household income in Rockingham County was $72,600 (USDOC 2007).

Matt Poole/USFWS

Cattails on Stubbs Pond

In the region around Great Bay Refuge, the major economic participant is the Pease International Tradeport. The Tradeport is a 3,000-acre business and aviation industrial park located at the former Air Force Base that was developed by the Pease Development Authority (PDA) after the closure of the base in 1991. It has more than 200 tenants, 5,100 employees, and 3.9 million square feet of new construction and renovated space for businesses (Greater Portsmouth Chamber of Commerce 2006). The Tradeport also includes the Portsmouth International Airport at Pease which is used both for military aviation by the New Hampshire Air National Guard and for civilian aviation.

The PDA has marketed the Tradeport as an ideal location for businesses interested in global trade because of to its proximity to major highways, an international airport, and the marine Port of New Hampshire. Companies located at the Tradeport also benefit from the State's lack of a broad-based tax system. Some of the amenities provided by the Tradeport include hotels, restaurants and banquet facilities, golfing, personal and commercial banking, copy and printing services, and job training and continuing education (PDA 2006).

The expanding business center of the city of Portsmouth is less than 1 mile away from the Tradeport. Portsmouth is a significant commerce center in New

England (GPCC 2006). In addition to being accessible by five major highways, Portsmouth is served by the Boston and Maine Railroad. It is New Hampshire's only ice-free deep-water port with a Foreign Trade Zone. Lumber, fuel oils, salt, gypsum, scrap metal, and other materials are shipped from the Tradeport.

PSNH's wood burner along the Piscataqua River in Portsmouth is another major part of the economy. As mentioned before, it uses over 400,000 tons of wood chips annually to run, most of which comes from suppliers in New Hampshire (*http://www.psnh.com;* accessed May 2011*)*.

Portsmouth is also home to many shops, businesses, galleries, museums, restaurants, and the Portsmouth Naval Shipyard, which has been in operation since 1800. As the second oldest city in the State, Portsmouth has a prominent cultural heritage that attracts many visitors to historic sites such as Strawberry Banke. In nearby Durham, UNH adds to the vitality of the area's social and cultural resources.

Resource-based Recreation and Tourism

The natural beauty of New Hampshire has attracted many visitors to its mountains, forests, lakes, and seashore. Visitors to the State have cited visiting beaches, State parks or national forests, and opportunities for hiking, skiing, wildlife watching, and outdoor recreation as reasons for visiting New Hampshire (INHS 2009a). Tourism is an important economic contributor in New Hampshire, as 10 percent of private sector employees work in the "accommodation and food services" sector (NHES 2009). The tourism industry has seen a recent slowing due to the larger economic slowing of the country, however, meals and rooms taxes paid by tourists grew 2.3 percent in 2008, totaling $132.9 million (INHS 2009b).

The conservation of open spaces and their associated wildlife recreation activities provide economic benefits to the local and regional community. A report by the Trust for Public Land (TPL) titled "The Economic Benefit of Parks and Open Spaces" found that throughout the nation, parks, protected rivers, scenic lands, wildlife habitat, and recreational open space help support a $502-billion tourism industry (TPL 1999). In New Hampshire, the estimated annual value of open space to the economy totaled $8 billion, representing 25 percent of the State's local economy and contributing $891 million in State and local taxes (TPL 1999).

Another report by the Service found that national wildlife refuges in the lower 48 States attracted 34.8 million visitors in 2006 and generated $1.7 billion of sales in regional economies (Carver and Caudill 2007). Wildlife refuges, such as Great Bay Refuge, provide an opportunity to generate revenue through recreational activities. In 2006, the combined total revenues from wildlife watching, fishing, and hunting in New Hampshire was $520 million (USFWS and USDOC 2007) (table 3.6).

Table 3.6. Revenues from Wildlife-associated Recreation by Residents and Non-residents in New Hampshire.

	Total Participants	Total Expenditures	Total Participants	Total Expenditures
Activity	**2001**		**2006**	
Wildlife watching	450,000	$200,010,000	710,000	$273,769,000
Fishing	164,000	$186,436,000	230,000	$172,413,000
Hunting	53,000	$55,775,000	61,000	$74,467,000
Totals	**667,000**	**$442,221,000**	**1,001,000**	**$520,649,000**

From the U.S. Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau. 2001 and 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

Part II. The Refuge and its Resources

Refuge Administration

Staffing and Budget

When the refuge first opened in 1992, its staff consisted of a refuge manager, assistant manager, and an office administrative assistant. A biological technician was also on staff for a few years. In 2006, the Service implemented a Regional Workforce Plan which included a decision to de-staff Great Bay Refuge. Since 2008, Great Bay Refuge has been administered by Parker River Refuge in Newburyport, Massachusetts (see table 3.7).

Table 3.7. Refuge Staffing and Budget, 2005 to 2011.

Fiscal Year	Total Budget (Including Salaries)	Full-Time Staff
2005	$135,800	1
2006	$159,410	1
2007	$264,336	1
2008	$124,857	0.33
2009	$61,108	0*
2010	$67,740	0*
2011	$65,240	0*

**Note: Staff from Parker River Refuge administers Great Bay Refuge.*

Refuge Facilities

From 1992 through the summer of 2001, the refuge headquarters was located on the second floor of the former Newington Town Hall on Nimble Hill Road in Newington. The current headquarters was built in 2001, and is located past the electronic gate at the refuge entrance on Merrimack Drive, next to the former Weapons Storage Area. The automated entrance gate is timed to be open from dawn to dusk. The headquarters building houses staff space, a reception area, and a small meeting room. This office also provides office space for two regional Service staff: a regional wildlife biologist and a regional Geographic Information Systems (GIS) specialist. Map 3.2 displays the existing location of facilities.

Other refuge facilities include a house, maintenance building, and a visitor parking lot with adjacent interpretive kiosk, public restroom facility, and bicycle rack. Two pedestrian trails leave from the parking lot. These trails are described in more detail under the subheading “Public Use Programs” below.

Refuge Revenue Sharing

National wildlife refuges also directly contribute to local economies through shared revenue payments. Federally owned land is not taxable; but, under the provisions of the Refuge Revenue Sharing Act, the Service pays annual refuge revenue sharing payments to municipalities or other local units of government where there are national wildlife refuges. Land in public ownership requires little in the way of services from municipalities, yet it provides valuable recreational opportunities for local residents. Table 3.8 lists the payments made to the town of Newington since 2000.

Map 3.2. Great Bay National Wildlife Refuge Existing Conditions

Table 3.8. Great Bay Refuge's Refuge Revenue Sharing Payments to the Town of Newington, 2000 to 2010.

Fiscal Year	Newington, NH
2000	$36,277
2001	$37,028
2002	$41,550
2003	$39,935
2004	$35,323
2005	$39,892
2006	$36,922
2007	$35,702
2008	$27,699
2009	$26,028
2010	$18,340

Special Use Permits

The refuge manager issues special use permits on a case-by-case basis after determining whether a use is compatible with refuge purposes. All special use permits have a 1-year term. The refuge has issued special use permits for the following types of activities:

- Wildlife Inventories and Research.
  - Christmas Bird Counts (New Hampshire Audubon).
  - Wood wasp trapping (U.S. Forest Service).
  - Dragonfly surveys.
  - Study of contaminant effects on frog development (UNH).
  - Owl surveys (New Hampshire Audubon).
  - Research on prescribed burns and mowing (UNH Graduate student).

- Educational Programs.
  - Cub scout merit badge tour.
  - UNH Video Services for educational films and television programs.
  - UNH fire ecology class field trip.
  - UNH geology class field trip.
  - UNH wetlands delineation class.
  - Nashua Fish Hatchery education exhibit collecting fish and vegetation.

Research

Refuge staff, graduate students, conservation organizations, and others have conducted numerous studies on the refuge. A sampling of those efforts follows. Additional information on these studies can be obtained from refuge headquarters.

Great Bay National Wildlife Refuge Fish Survey Report (Brown 2008). In the fall of 1992, the Service's Laconia Office of Fishery Assistance conducted a survey of fish present in the refuge's three ponds. They conducted surveys at Upper Peverly, Lower Peverly, and Stubbs Ponds using an 18.0 foot long (5.5 m) electrofishing boat (boom-type with direct current). In 2007, they repeated the survey to determine if there were any significant changes in fish species composition and abundance.

Forest Health Assessment of Great Bay National Wildlife Refuge (2007). In the summer and fall of 2006, the U.S. Department of Agriculture (USDA) Forest Service, Durham Field Office–Forest Health Protection staff conducted an assessment of the general overall health and condition of the refuge's forested areas. Appendix H includes their final Forest Health Assessment report.

Geological Assessment of Cores from the Great Bay National Wildlife. Refuge (2007) In 2006, U.S. Geological Survey (Foley et al. 2006) sampled two wells on the refuge to analyze geological sources of arsenic and zinc in ground and surface waters.

Estimating Egg Mass Abundance of Pool-breeding Amphibians (2003). In 2002 to 2003, a regional study estimated the numbers of wood frog and spotted salamander egg masses in three to four pools on the refuge (Evan H. Campbell Grant et al. 2005).

Investigation of Frog Abnormalities on National Wildlife Refuges in the Northeast U.S (2003). From 1997 to 2001, the Service conducted a regional study to determine if any national wildlife refuges had sites with frequently observed frog abnormalities. The study evaluated if the prevalence of abnormalities at a site was consistent within a season and among years, as well as investigated possible causes for abnormalities.

Field Metabolic Rate of Wild Turkeys in Winter (Coup and Perkins 1999). Coup and Perkins (1999) used the refuge as the primary study site to investigate the field metabolic rate of free-ranging eastern wild turkeys.

Refuge Natural Resources

Topography and Soil

The refuge's topography is typified by gently rolling coastal hills ranging in elevation from sea level to 100 feet above sea level. The refuge has a variety of soil types, mostly from marine and glacial parent materials. The most common soil type on the refuge is Boxford silt loam, and much of the rest of the refuge is sandy and silty loams. Table 3.9 describes the major soil types on Great Bay Refuge.

For more detailed information on the area's soils, visit the Web Soil Survey online at: *http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm* (USDA-NRCS 1994; accessed May 2012). The Web Soil Survey application allows users to generate soil maps for locations throughout the United States, as well as read detailed soil descriptions.

Table 3.9. Major Soil Types on Great Bay Refuge from the Soil Survey of Rockingham County (USDA-NRCS 1994).

Soil Name	Soil Use and Vegetation	Soil Composition	Parent Material	Slope	Drainage
Boxford	Most areas are either forested or used for growing forage crops for livestock, silage corn, and vegetables. Some areas are used for urban structures. Dominant tree species are white pine and a mixture of northern hardwoods.	Silt loam	Marine	0 to 8 percent	Moderately well-drained
Smoothed Udorthents	Most areas are used for urban development, landfills, or left idle.	–	Anthropogenic	–	Not rated
Pennichuck Channery	Gently sloping areas are used for row crops, truck, farming, grassland, and orchards. Sloping areas are used as orchards, grassland, and woodland. Forested areas are mostly white pine, red oak, white oak, red maple, and sugar maple.	Very fine sandy loam	Glacial till	0 to 15 percent	Well drained

Soil Name	Soil Use and Vegetation	Soil Composition	Parent Material	Slope	Drainage
Hoosic	Most areas have been cleared and are used for pasture or to grow hay, corn, small grains, vegetable crops, and deciduous fruit. Forested areas contain sugar maple, oak and hickory species, and American beech.	Fine sandy loam	Glacial outwash	3 to 15 percent	Somewhat excessively drained
Squamscott	Most areas are forested. Principle trees are white pine and red maple. Some areas that are drained are in cropland.	Fine sandy loam	Marine	0 to 5 percent	Poorly drained

Habitat Types and Associated Wildlife

Despite its relatively small size, Great Bay Refuge supports a diversity of habitat types (table 3.10). The upland and freshwater habitats of the refuge include oak-hickory forest, shrublands, grasslands, forested and shrub wetlands, and impounded wetlands. The refuge is 60 percent upland forest or rocky upland, 18 percent grassland or shrubland, and 22 percent freshwater or saltwater wetland, including open water and forested wetlands. The refuge also has a small amount of rocky shoreline and salt marsh habitat. Maintaining these habitat types on the refuge contributes to the protection of critical habitats throughout the Great Bay Estuary.

Table 3.10. Natural Community Types and Associated Habitats on Great Bay Refuge.

Habitat	Habitat Acres	Natural Community Type	Acres
Salt marsh	36	High salt marsh	23
		Low salt marsh	6
		Low/high salt marsh complex	5
		Brackish marsh	2
Rocky shoreline	2	Coastal rocky headland	2
Freshwater impoundments	62	Open-basin cattail marsh	45
		Open water/beaver impoundment	14
		Tall graminoid emergent marsh	3
Forested and scrub-shrub wetlands and vernal pools	149	Low red maple–elm/musclewood/ladyfern silt forest	69
		Seasonally saturated red maple swamp	38
		Black gum–red maple basin swamp	14
		Speckled alder basin/seepage shrub thicket	12
		Red maple–sensitive fern-tussock sedge basin/ seepage	12
		Graminoid-forb-sensitive fern seepage marsh	2
		Wet gravel pit-artificial pondshore	<1
		Short graminoid-forb meadow marsh/ mudflat	<1

Habitat	Habitat Acres	Natural Community Type	Acres
Oak-hickory forest	659	Mesic Appalachian oak–hickory forest	375
		Dry mesic Appalachian oak–hickory forest	147
		Dry Appalachian oak-hickory forest	90
		Plantation	25
		Forest on fill	12
		Red pine forest woodland	8
		Dry-mesic field/shrubland; reverting to forest	2
Shrubland	26	Dry-mesic field/shrubland	23
		Mesic field/shrubland	3
Grassland	169	Dry field	95
		Dry to wet field mosaic	19
		Dry-mesic field	55
		TOTAL	**1,103**

**Table summarized by refuge staff based on field visits by Sperduto (2000, 2010) and GIS analysis. Acres rounded up to nearest whole number.*

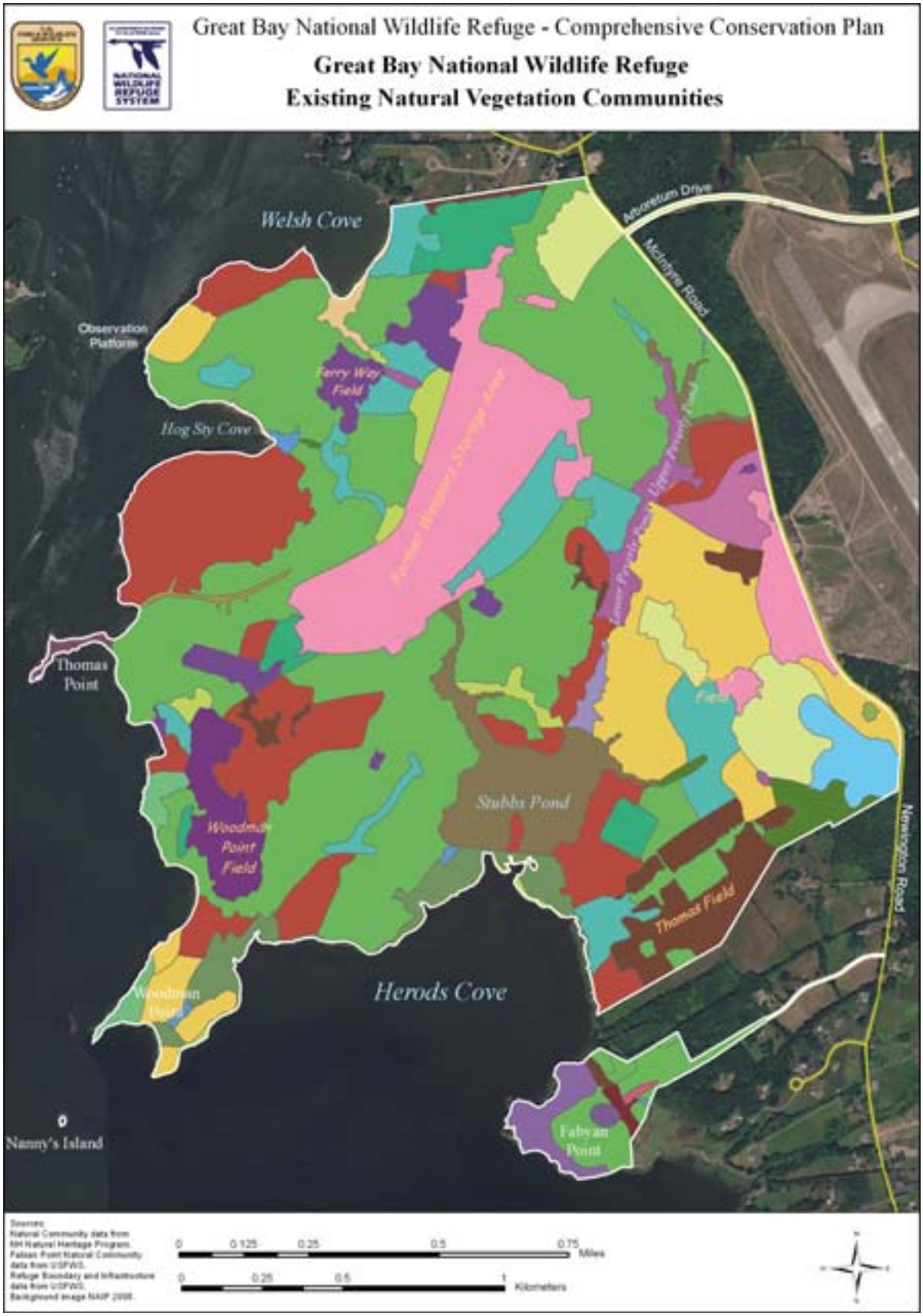
In 2000 and 2010, the New Hampshire Natural Heritage Bureau (NHB) identified and mapped natural community types and other cover types on the refuge (Sperduto 2000 and 2010) (map 3.3). Natural communities are recurring assemblages of plants found in particular physical environments that are distinguished by three characteristics: 1) a definite plant species composition; 2) a consistent physical structure (such as forest, shrubland, or grassland); and 3) a specific set of physical conditions (such as different combinations of soils, nutrients, drainage, and climate conditions). Most wildlife species do not select habitats on as fine a scale as natural community types. Therefore, we have combined some of the natural community types with broader wildlife habitat types. Both classifications are important to understanding and maintaining the refuge's biological diversity, integrity, and environmental health.

Exemplary natural communities are those that have been minimally impacted by humans, contain a species composition representative of the type, and have intact ecological processes that maintain these species. The NHB identified the following five "exemplary" natural communities on Great Bay Refuge (*http://www.nhdfl.org/natural-heritage-and-habitats/;* accessed December 2011):

- Dry Appalachian oak–hickory forest.
- Mesic Appalachian oak–hickory forest.
- Coastal rocky headland.
- Black gum–red maple basin swamp.
- High salt marsh.

The refuge also supports an additional rare natural community type: red maple-elm-lady fern silt forest. In 1999, NHB mapped several stands of this community on the refuge, but, at that time, none of them were considered "exemplary" because they were relatively young and had significant infestations of invasive plants. However, these stands are still important for the refuge because the community type is rare in New Hampshire (critically imperiled/imperiled in New

Map 3.3. Great Bay National Wildlife Refuge Existing Natural Vegetation Communities



Legend for Map 3.3

Hampshire) and there are no documented "exemplary" occurrences of red maple-elm-lady fern silt forest in the State (Bowman 2012 personal communication).

Estuarine Habitats

Salt Marsh

Several areas of substantial salt marsh, totaling approximately 36 acres, occur along the refuge's shore, with the best developed occurring behind Woodman Point and Stubbs Pond. The low salt marsh is dominated by smooth cordgrass, while salt meadow cordgrass, spike grass, and black-grass are dominant in the high salt marsh. Small brackish marshes occur at the upland edge of salt marshes where drainages meet the bay, and are dominated by narrow-leaf cattail and sedge species. NHB reported several rare plants in the refuge's salt marsh, including seaside mallow, a State-listed threatened species (NHNHB 2009). Estuarine communities are uncommon in New Hampshire because of the limited shoreline within the State and the intense development and disturbance near much of the coastal salt marsh.

In 1992, prior to refuge establishment, the town of Newington hired a contractor to spray the pesticide *Bacillus thuringensis* serotype *israelensis* (Bti) on marshes to control the extensive mosquito breeding occurring in areas of the marsh heavily impacted by humans. Beginning in 1996, in an effort to eliminate chemical application on the marshes and restore fish and wildlife habitat, the refuge initiated four open marsh water management (OMWM) projects. In total, 16.3 acres were completed at Herods Cove, 9.9 acres at Woodman Point, and 3.4 acres at Welch Cove. We have not created any additional OMWM projects since then, as we have completed all the opportunities for OWMN on the refuge.

OMWM objectives included elimination of invasive plants (e.g., *Phragmites*, cattail); restoration of native salt marsh vegetation, such as wigeon grass; and creation of refugia habitat for the mummichog minnow. This minnow is a predator of mosquito larvae and its presence could eliminate the need to spray Bti for mosquito control. Various techniques were used. Ditch plugs were constructed to block man made drainage ditches and create open water habitat. Pannes (beginning at 2 inches and gradually sloping to 24 inches in depth) were excavated to increase open water habitat and to facilitate wading bird access. Sumps (2-foot-deep depressions) were excavated within pannes to ensure minnow survival during drought conditions. In some areas, shallow connector ditches were also excavated to allow minnow access between pannes.

Rocky Shoreline

Woodman Point and Thomas Point support approximately 2 acres of southern New England coastal rocky headland, considered a rare exemplary community type by NHB. The headlands have a largely natural character with narrow vegetation zones representing both estuarine and upland plant associations. The upland portion at Thomas Point is dominated by red cedar and some black oak, red oak, alders, bayberry, and common juniper. The salt marsh and rocky areas of the point support estuarine plants such as seaside goldenrod (NHNHB 1990).

Large red and white pines grow on the headlands, providing important perch and roost trees for bald eagles wintering on Great Bay. The refuge has suitable eagle nest sites, although there is currently only one eagle nest on Great Bay Refuge. Two red pine forests (approximately 4 acres each) are found by Woodman Point and west of the Margeson Estate. These pines are estimated to be about 150 years old and are natural communities disjunct from larger patches found primarily in the White Mountains region (Sperduto 2010).

The 0.25-acre Nannie Island off Woodman Point is the only island that is part of the Great Bay Refuge. A mallard pair occasionally nests on the island. Some

invasive plants are present. The island was evaluated for tern nesting possibilities but was deemed unsuitable because of its small size and susceptibility to predation and human disturbance.

Eelgrass and Shellfish Beds
Two other regionally significant habitat types lie just off the refuge boundary in State waters: eelgrass beds and shellfish beds. Their protection is a priority amongst partners in the Great Bay Estuary. Refuge staff, as a partner in these protection efforts, conduct informal monitoring to evaluate if refuge management actions are impacting these habitats.

Eelgrass beds are an essential habitat in the Great Bay Estuary and the basis of an estuarine food chain, providing food for migrating and wintering waterfowl and habitat for juvenile fish and invertebrates. Eelgrass beds are particularly important to juvenile rainbow smelt, Atlantic silversides, nine-spined sticklebacks, alewife, and blueback herring. Eelgrass leaves slow water flow, filtering suspended sediments from the water column (Short et al. 1992a). A dramatic decline in eelgrass beds in 1989, to only 300 acres, was linked to an outbreak of the *Labryrinthula zosterae* slime mold, commonly called "wasting disease." Eelgrass populations recovered from the disease but have been showing a slow steady decline since 1990 (PREP 1999). Reduced water clarity from suspended sediments, nutrient loading, and decreased filtering capacity may be contributing to eelgrass populations decline. This is an ongoing management issue in Great Bay Estuary (Short et al. 1992b). A significant eelgrass bed exists in Herods Cove, part of which is adjacent to the refuge boundary.

The Great Bay Estuary and its tributaries support 52 acres of oyster beds, over 2,500 acres of scattered clam flats, and significant areas with blue mussel beds, razor clams, and scallops. Soft-shell clams are an important food source for wintering black ducks. The estuarine habitat extending from Herods Cove to Nannie Island is an important nursery area for oysters and clams, supporting more than half of the spawning oyster population in the bay (PREP 2009).

Pondside color

Matt Poole/USFWS

Freshwater Impoundments
Historical Uses
The refuge has five freshwater impoundments: Lower Peverly Pond, Upper Peverly Pond, Stubbs Pond, and two small impoundments in the Weapons Storage Area and along Ferry Way Trail. Upper Peverly Pond (12 acres), Lower Peverly Pond (7 acres), and Stubbs Pond (44 acres) are interconnected by Peverly Brook and fed by springs and small tributaries. These impounded wetlands are part of the 907-acre Peverly Brook watershed.

Upper and Lower Peverly Ponds were constructed as a water supply for the city of Portsmouth around 1900. From 1956 to 1959, the dike between the two ponds was improved with a spillway and a new dam. At the same time, Lower Peverly Pond was dredged to provide a swimming area and the water control structure boards were raised 3 feet. Maps 3.4 through 3.6 are aerial photographs that show these changes to the freshwater impoundments from 1952 to 1998 (Public Archaeological Laboratory, 2010).

The Air Force used Upper Peverly Pond for boating and angling, and used Lower Peverly Pond as a recreational swimming pond. Stubbs Pond area was a salt marsh until it was diked for mosquito control in 1963. Several years later, the dike was raised to provide for a warm water fishery and the pond was named after General Stubbs. The Air Force managed vegetation in all three ponds to improve recreational fish habitat. They also stocked the three ponds with recreational fish (table 3.11). No stocking has occurred since the refuge was

Map 3.4. Great Bay National Wildlife Refuge Area–July 1952

Map 3.5. Great Bay National Wildlife Refuge Area–October 1962

Map 3.6. Great Bay National Wildlife Refuge Area–Circa 1998

established in 1992. Table 3.18 provides a description of the current fisheries resources in these ponds.

Prior to 1980, the Air Force's impoundment management generally consisted of herbicide application. Records indicate that Upper and Lower Peverly Ponds were treated with Diquat in 1966. Generally, management activities were not documented; however, a 1980 Fishery Management Plan by the Air Force stated that annual programs to control algae growth in all three ponds were implemented. The 1980 plan recommended minimizing the application of herbicides and suggested mechanical control instead. In 1979, 7 acres of Stubbs Pond were mechanically cleared. In the 1980s, plastic tarps were placed over weeds in Stubbs Pond to prevent further growth, but it appears that the tarps were largely ineffective. During the 1980s, vegetation (documented as *Chara spp.*) was estimated to be covering 90 percent of the surface area of Stubbs Pond. Sometime in the last several decades, wild rice was introduced to Stubbs Pond and has become well established and abundant. Wild rice, which is uncommon in the State, is an important source of food and cover for wildlife (NHFG 2012 personal communication).

Table 3.11. Fish Stocking During Air Force Management of Upper Peverly, Lower Peverly, and Stubbs Ponds.

Pond	Year Stocked	Species
Upper Peverly	1956	Rainbow and brook trout
	1965 and 1966	Largemouth bass
	1972	Crayfish
Lower Peverly Pond	1956	Rainbow and brook trout
	1965 and 1966	Largemouth bass
Stubbs Pond	1965 and 1966	Largemouth bass
	between 1971 and 1981	Alewife (stocked 4 times)
	1972	Crayfish

Source: Great Bay Refuge Fisheries Management Plan, 1994.

Stubbs Pond (Recent Management)
The 44-acre Stubbs Pond is a freshwater impoundment currently managed primarily for migratory birds, with a focus on spring and fall migrating waterfowl. The goal is to control the monoculture of cattail vegetation, and to increase vegetation diversity by opening up areas and increasing the ratio of open water to emergent vegetation while controlling invasive purple loosestrife and phragmites. Water level management has fluctuated from year to year, in part because of the complexities in managing Stubbs Pond to address multiple concerns. Large bur-reed, a State threatened species, has been found in the pond.

Since the installation of a new water control structure in 1996, cattail growth has been excessive, reducing the proportion of open water to vegetation. Mowing and re-flooding were used beginning in 1997 to reduce cattail coverage. In 1999, water levels were not dropped until August, and moist soil vegetation production was poor. Subsequently in 1999, the tidal gates were opened October 26 and closed on December 1 to coincide with extremely high tides to create a tidal flush as recommended by Leigh Fredrickson of the University of Missouri (Frederickson 1999 personal communication). Fredrickson also recommended

treating a small (10 acre) area of cattails with glyphosate. However, due to permits required by the State of New Hampshire, the planned glyphosate treatment was pushed back until August of 2000.

In the summer and early fall of 2002, Stubbs Pond was drawn down to allow mowing of 4 acres of cattail along the western edge of the pond and west of the main water channel. During late fall of 2002, we blocked all three pipes that run under the dike at Stubbs Pond to allow water levels to rise and be held at higher levels than allowed by the water control structure. When the pipes are open, water levels can never exceed approximately 6 to 6.5 feet on the water control structure gauge. With all boards in place, water levels rose over the winter to around 7.0 feet. Stubbs Pond was kept as full as possible, between 7.1 and 7.3 feet, throughout the summer of 2003 in an attempt to control cattail growth. By late August the cattail stands were reduced by 25 percent. The entire southeastern quadrant of Stubbs Pond, normally full of cattail, remained almost cattail free. The western portion of the pond that was mowed in the fall of 2002 had some cattail reemerge during the summer, with some small pockets of open water. We also observed increased populations of other plant populations important for wildlife, including large bur-reed, soft stem bulrush, wild celery, and arrowhead. There were also fewer purple loosestrife plants in bloom during mid to late summer.

On September 11, 2003, the refuge staff began to lower the water level in Stubbs Pond to provide some feeding habitat for migrating birds. By mid-November the water level was 4.3 feet. Dead cattail stems were evident in many areas of the pond as water levels were drawn down. On November 18, all boards were put back in the control structure to allow water to rise to full pool over the winter.

During 2004, water levels in Stubbs Pond were again maintained at an operating level of around 7.0 feet during the spring and summer in an effort to further stress growth of cattail. This effort was apparently successful and reduced cattail populations another 25 percent. Cattail stands were now limited to several larger clumps around the center island and along the northwestern and eastern edges of the pond. On September 10, the refuge staff began lowering the water levels to provide habitat for the fall bird migration. Water levels reached a low of 3.4 feet on November 17, when all boards were put back in to allow the pond to raise to full pool over the winter.

It appears that spring drawdown of this pond allows cattail and purple loosestrife to increase, while inhibiting other more desirable species. Therefore, current plans are to keep Stubbs Pond high during the spring and summer to discourage cattail growth. A drawdown in early fall benefits migratory birds. If weather permits, it may be possible to mow, spray, or burn cattail stands in the fall before refilling the pond in the winter to early spring.

Stubbs Pond and the adjacent bay are important migratory and wintering habitat for waterfowl. It is a particularly important to area waterfowl during spring and fall staging as evidenced by the number and variety of waterfowl species observed on the pond, particularly black ducks. However, no regular or formal quantitative surveys for waterfowl use have been conducted by the refuge or the State. In winter of 2010, Parker River staff recruited volunteers to start formal surveys for all three impoundments during spring and fall waterfowl migration. Two surveys were conducted in December and four surveys in April. Table 3.12 lists the most abundant waterfowl species recorded during the survey.

Stubbs Pond

USFWS

Previous observational data indicates that waterfowl use of Stubbs Pond is highest in fall (September to November). NHFG (2011) has also reported that it is common to observe more than 500 ducks and geese in Stubbs Pond in September. Due to this, NHFG and the Service use Stubbs Pond for an important waterfowl banding program during Septembers. Winter peak waterfowl use is comparatively higher in the bay (a total of 676 individuals; most common species are Canada goose, American black duck, and mallard) than in Stubbs Pond (94 individuals). However, waterfowl use of Stubbs Pond is higher than that of the bay during the springtime.

Table 3.12. Most Common Species Detected During Waterfowl Survey of Stubbs Pond, 2010.

Month	Species	Number Observed
April 2010	Ring-necked duck	100
	Ruddy duck	94
	Wood duck	14
	American wigeon	12
	Canada goose	10
December 2010	American black duck	50
	American coot	20
	Mute swan (nonnative)	17
	American wigeon	6

The amount of emergent wetland habitat has declined significantly throughout North America along with apparent declines of marsh-dependent birds. Between 1999 and 2003, five marsh bird surveys were completed for the refuge. Virginia rail (0 to 5 birds per survey) and marsh wren (2 to 9 birds per survey) were consistently found using the impoundments. Other species that occasionally bred in the impoundments included least bittern, sora rail, common gallinule, pied-billed grebe, and king rail. Most of the marsh and wading birds occurred at Stubbs Pond. Our strategy at Stubbs Pond of maintaining a balance of open water to emergent vegetation with an emphasis on vegetative diversity provides the most benefit to a majority of marsh and wading birds. Changes in water levels, ratios of mud flats to open water areas, invertebrate communities, and amount of emergent plant cover in marsh habitats could affect habitat quality for marsh birds.

In 2002 and 2006, an evaluation of all three dams on Upper and Lower Peverly Ponds and Stubbs Pond occurred. According to the 2006 Safety Evaluation of Existing Dams (SEED) report, Stubbs Pond Dam is in "poor" condition. Poor condition is defined by "a potential dam safety deficiency is clearly recognized for normal loading conditions. Corrective actions to resolve the deficiency are recommended." The "poor" rating for Stubbs Pond Dam was primarily due to two deficiencies: erosion around three steel pipes embedded in the dam's embankment, and the presence of vegetation in the dam's emergency spillway. Continued deterioration of Stubbs Pond would likely jeopardize the refuge's ability to maintain the pond as open water habitat for migratory birds (Brownell 2011 personal communication). The following specific recommendations from the 2006 SEED report are being addressed as noted below.

Recommendations	Refuge Actions in Response
Remove 3 steel pipes that lie embedded in the embankment and backfill the area	Future project targeted by 2014
Mow embankments, remove trees and other debris from spillway	Ongoing
Remove brush and debris on dam and side slopes	Ongoing
Install riprap in emergency spillway where needed	Future project targeted by 2014
Enlarge emergency spillway and left abutment; consider doing this during brush and debris removal and riprap installation	Evaluating
Repair wave erosion on escarpment near Herods Cove	Monitoring, but repairs would conflict with horseshoe crab spawning habitat

A fish passage structure was installed in 1995 to benefit alewife and blueback herring migration, but was not operated until the spring of 2003. Historically, we have opened the fish passage in late April to allow alewife and blueback herring migration into Stubbs Pond through early July. The fish passage structure requires about 1 to 1.5 feet of running water to be effective for fish. It is primarily designed to operate at high tides since tidal mud flats in Herods Cove at low tide prevent fish reaching the ladder. Outside of fish spawning season, the fish ladder is essentially not operational by design. In fact, there are times of the year when no water is flowing through the fish ladder. We have plans to evaluate this original design to see if the existing fish ladder could be improved

to enhance fish passage. Operation of the fish ladder does not impact our ability to manage water levels in Stubbs Pond for migratory birds, except possibly in extremely dry years (Brownell 2011 personal communication).

Upper Peverly Pond (Recent Management)
A new water control structure was installed on the 12-acre Upper Peverly Pond in 1999. The pond was drawn down several times during spring with positive vegetative and waterfowl population response to this management. During 2004, a botanist inventorying the refuge for invasive species discovered that brittle waternymph had become widely established in the pond. Brittle waternymph is an annual exotic plant with no easy control methods. The water level in the pond was held high all year to contain this invasive plant until more is determined on how to control it. It is used by a limited number of waterfowl and marsh birds such as great blue heron, ring-neck duck, wood duck, and bufflehead for foraging and resting during migration. According to the 2006 SEED report, Upper Peverly Pond Dam is in "fair" condition. Fair condition is defined by "no existing dam safety deficiencies are recognized for normal loading conditions. Infrequent hydrologic and/or seismic events would probably result in a dam safety deficiency." The following specific recommendations from the 2006 SEED report are being addressed as noted below.

Recommendations	Refuge Actions in Response
Remove beaver dams from spillways	Ongoing
Weld or lock cover on outward valve	Done
Back fill existing animal burrows	Not needed
Lubricate valves	Done
Monitor seepage along abutment	Monitoring
Monitor crack and depression on dam	Monitoring
Remove debris and maintain embankment	Ongoing as needed and as resources allow

Lower Peverly Pond (Recent Management)
The 7-acre Lower Peverly Pond has limited water control capabilities given that its antiquated spillway is deteriorating. In 2005, plans were developed to repair the dike; however, the State denied the permits requesting further documentation of the need for repairs versus removal of the dam. Without water control capability, this pond is used primarily to pass water from Upper Peverly to Stubbs Pond. Brittle waternymph was found in this pond in 2004. Lower Peverly Pond supports a limited number of waterfowl, notably some wood ducks and black ducks. An occasional bufflehead, common merganser, and a few ring-necked ducks can be observed during the spring and fall migration.

According to the 2006 SEED report, Lower Peverly Pond Dam is in "unsatisfactory" condition. Unsatisfactory condition is defined by "immediate actions to rehabilitate or decommission the dam are recommended." The "unsatisfactory" rating for Lower Peverly Pond Dam was primarily due to one deficiency: the deteriorating and failing spillway. The following specific recommendations from the 2006 SEED report are being addressed as noted below.

Recommendations	Refuge Actions in Response
Monitor and inspect failing spillway weekly	Ongoing, but not weekly
Monitor beaver activity and remove debris from spillway	Ongoing
Remove trees and brush from embankment	Determined not necessary
Rehabilitate or decommission dam	See chapter 4, objective 1.3 under each alternative for proposed actions

Forested and Scrub-shrub Wetlands and Vernal Pools
Several vegetated wetlands habitat types occur on the refuge as noted in table 3.10. Approximately 81 percent of the wetlands types on the refuge are dominated by trees, mainly red maple and some black gum. The remaining 19 percent of vegetated wetlands is shrub-scrub wetlands dominated primarily by speckled alder. Map 3.3 shows the locations of the forested and scrub-shrub wetlands. Vernal pools, which are not mapped, are a critical habitat feature that is imbedded in each of these wetlands types.

NHB discovered a black gum-red maple basin swamp on the refuge that contains dozens of old black gum. Some of the trees were likely more than 200 years old, although a more detailed assessment is needed. Seepage swamps on the refuge have the potential for supporting rare plants (Sperduto 2000). Seepage swamps are forested wetlands with plants indicative of groundwater seepage such as spicebush, horsetail, marsh marigold, American bittersweet, and certain sedges.

In 2001, the Northeast Amphibian Research and Monitoring Initiative was launched on a host of national wildlife refuges and state parks, including Great Bay Refuge, due to increasing concern over amphibian declines and malformations. The goal of the study was to establish baseline conditions and to assess population trends of vernal pool breeding amphibians (e.g., wood frog and spotted salamander). An annual frog and toad calling survey, following the North American Amphibian Monitoring Program (NAAMP) protocol, was begun in 2000. The surveys on the refuge have yielded spring peeper, gray tree frog, wood frog, leopard frog, and American toad. Outside of this study, there has been no formal or comprehensive survey of vernal pool locations on the refuge.

The refuge records about 6 to 12 breeding American woodcock on the refuge each year. These birds use the speckled alder-shrub thickets that are scattered around the refuge for daytime resting and foraging areas. Woodcock prefer shrublands in close proximity to young hardwood forests for use as nest sites. The willow flycatcher prefers open habitat with scattered shrubs or forest edges, including willow thickets along streams, scrub-shrub wetlands, and brushy fields.

A 1-acre wetland was created in 1995 by installing a wooden water control structure to impound several drainage ditches in the former weapons storage area. This wetland holds water during the spring and early summer and goes dry during late summer. The vegetation is predominantly cattails, which support some marshbirds, such as sora and Virginia rails, plus many species of frogs.

Upland Habitats

Oak-hickory Forest
Many of the forests on Great Bay Refuge reflect their relatively recent agricultural history and are dominated by successional white pine or hardwoods. Although pine, hardwoods, and mixed stands are native to the area, the current overstory dominant tree species are not necessarily the best indicator of what natural community types occurred on the refuge. White pine stands are common and are generally a stronger indication of past land use history than they are of

the long-term potential of a site. NHB used the total composition of plant species, in combination with soil attributes, to indicate community type (Sperduto 2000).

In 1990, NHB surveyed the entire former Pease Air Force Base. In that survey, Woodman Point was described as a transitional forest between central and northern hardwood regions. It has large mature red pines that appear to be natural in origin. The drier portion supports large shagbark and pignut hickories, while the more mesic area has large white and red oaks (NHNHP 1990). A 2010 survey by NHB determined that the red-pine woodland is about 150 to 170 years old and is most likely a natural occurrence.

Much of the rest of the upland area of the refuge was mapped as oak-hickory forest. The natural community types include dry Appalachian oak forest and mesic Appalachian oak-hickory forest. The refuge falls within the northern extent of the central hardwoods forest region with forests dominated by oak and pine. The dry to mesic Appalachian oak forests on the refuge are characterized by southern species that reach the northern extent of their ranges in this region. It is distinguished from dry red oak–white pine forests, which tend to lack significant representation of southern or Appalachian species such as shagbark hickory. Oak forests appear to be fire-dependant over long periods in other regions of the country. Some of these forests may succeed to other overstory species in time due to lack of adequate red oak regeneration, and from increases in American beech on drier sites, and sugar maple and American beech on more mesic sites. Repeated fire would tend to knock back fire-sensitive species like American beech and sugar maple. As such, any natural, semi-natural, and/or controlled fire regimes may be necessary for the long-term maintenance of oak and hickory on some sites (Sperduto and Nichols 2004). Under climate change projections, the range of the oak-hickory forests is likely to shift northwards, making southern New Hampshire the middle of its range. This shift may preclude succession to northern hardwood as described above. Changing climate conditions may also increase likelihood of fire, which would sustain oak-hickory forests.

Pine Plantations
There are five pine plantations of varying size on the refuge. These pines were dated to the late 1970s, and were most likely planted by the military as training exercises. The pines in these plantations are dying due to an unknown disease, and oak-hickory forest species are regenerating under the pine overstory. The conversion of these plantations to oak-hickory forest will be monitored to ensure a healthy forest ecosystem with minimum invasive plants.

Upland Shrub Habitat
The refuge currently maintains approximately 26 acres of shrub habitat through periodic mowing or use of a hydro-ax to prevent succession to forest cover. These are mainly small units, less than 5 acres in size, and historically maintained as woodcock singing grounds. A management issue on the refuge that particularly affects grassland and shrub management is the prevalence of invasive species that quickly invade these areas if left unmowed. Autumn olive is particularly difficult invasive plant to control as it quickly invades open land habitat. Shrub habitat provides nesting and foraging habitat for birds of conservation concern including prairie warbler, blue-winged warbler, eastern towhee, and American woodcock. It also supports other thicket-dependent native species. Over the course of the next 15 years, we would let these small forest openings revert and manage for larger patches of shrub habitat that would provide better habitat for shrub-dependent birds and New England cottontail. We would also target sites were conditions are more conducive to shrub management (e.g., wet areas that naturally support alder and dogwoods).

Grassland

The refuge currently manages approximately 169 acres of grassland habitat, primarily in the former Weapons Storage Area, north of Woodman Point, along Ferry Way Trail, and the Thomas Field. Many of these grassland areas have a component of little bluestem as well as nonnative grasses. The largest grassland, approximately 70 acres comprised of 8 treatment areas, is in the former Weapons Storage Area. This grassland complex is managed using prescribed fire and mowing to control autumn olive and other woody plants. Most sections of the Weapons Storage Area were either mowed, hydro-axed, or burned in 1999 to prepare for a 2000 herbicide application to control autumn olive. The hydro-ax was also used to expand the grassland by clearing trees and shrubs at the southwest end of the weapons storage area. The 30-acre Thomas Field and 24-acre Woodman Point Field complex are mowed and hydro-axed. A sandy field north of the Weapons Storage Area has maintained itself as a little bluestem community without active management for over 10 years. This field is south of the northern most pine plantation (15 acres), which also support sandy soils, and potentially could be managed as a 20- to 30-acre grassland unit, contiguous with the grasslands in the Weapons Storage Area. The remaining grassy areas range from 2 to 4 acres and are mowed every 1 to 2 years to benefit woodcock.

Woodman Point looking north

Greg Thompson/USFWS

Grassland bird species recorded during surveys on the refuge from 2001 to 2003 included eastern meadowlark, bobolink, upland sandpiper, field sparrow, red-winged blackbird, American kestrel, and vesper sparrow. Brown thrasher and eastern towhee, two shrubland species, were also recorded. In 2003 and 2004, at least one pair of upland sandpipers was observed using the former Weapons Storage Area and the Thomas Field during the nesting season. The Thomas Field pair was observed nesting for the second year in a row.

The Pease Airport continues to support nesting upland sandpipers due to the large expanse of grassland habitat surrounding the runways. Excluding buildings, there are approximately 500 to 600 acres of grasslands surrounding the runways and taxiways. On average, a dozen pairs of upland sandpipers have nested at the airport in recent years. The only confirmed upland sandpiper breeding areas in New Hampshire are at Pease Airport and the refuge, although the species has been sighted at several other locations including Dover, Manchester, and southern Coos County (Hunt and De Luca NH Audubon 2011 personal communication).

Rare Plant Populations

The following four State-listed rare plants are documented on the refuge: large bur-reed, seaside mallow, black sedge, and wild lupine (NHNHP 2009).

Invasive Plants

Executive Order 13112 ("Invasive Species," dated February 3, 1999) defines an invasive species as a nonnative species "whose introduction does or is likely to cause economic or environmental harm or harm to human health." The Executive Order requires the National Invasive Species Council (Council) to produce a National Invasive Species Management Plan every 2 years. In January 2001, the Council released their first plan, which serves as a blueprint for all Federal actions on invasive species. The plan focuses on those nonnative species that cause, or may cause, significant negative impacts and that do not provide an equivalent benefit to society. The unchecked spread of invasive plants threatens the biological diversity, integrity, and environmental health of all refuge habitats. In many cases, they have a competitive advantage over native plants and form dominant cover types, reducing the availability of native plants as food and cover for wildlife. One report estimates the economic cost of invasive species in the U.S. at $137 billion every year (Pimentel et al. 2000). Up to 46 percent of the plants and animals federally listed as endangered species have been negatively impacted by invasive species (Wilcove et al. 1998, National Invasive Species Council 2001).

The Service's Northeast Region initiated an effort to systematically identify, locate, and map invasive plant species occurring on national wildlife refuge lands to provide a foundation for developing an effective integrated management plan. Refuges will use this information to guide the development of control, monitoring, and evaluation projects.

The Service Manual (620 FW 1.7G) provides the following guiding principles on managing invasive species on national wildlife refuges:

1. Manage invasive species to improve or stabilize biotic communities to minimize unacceptable change to ecosystem structure and function and to prevent new and expanded infestations of invasive species.

2. Conduct refuge habitat management to prevent, control, or eradicate invasive species using techniques described through an integrated pest management plan, or other similar management plan, the plans comprehensively evaluate all potential integrated management options, including defining threshold/risk levels that will initiate the implementation of proposed management actions.

3. Evaluate native habitat management activities with respect to their potential to accidentally introduce or increase the spread of invasive species and modify our habitat management operations to prevent increasing invasive species populations.

4. Refuge integrated pest management (IPM) planning addresses the abilities and limitations of potential techniques including chemical, biological, mechanical, and cultural techniques.

5. Manage invasive species on refuges under the guidance of the National Strategy for Invasive Species Management (USFWS 2003b) and within the context of applicable policy.

Great Bay Refuge initiated a baseline inventory and mapping of invasive species in 2002. Field surveys during 2002 through 2005 and 2008 detected 34 invasive species (table 3.13). Approximately 684 acres of the refuge have been mapped as infested and 13 acres are currently considered free from invasives. The remainder of the refuge still needs to be mapped, which will occur by 2013. Invasive species control methods used by the refuge include hand pulling with weed wrenches, annual mowing, and chemical and biological controls (for purple loosestrife).

Table 3.13. Invasive Plant Species on the Great Bay Refuge.

Common Name	Scientific Name	Approximate Number of Refuge Acres Affected
Amur honeysuckle	*Lonicera maackii*	Less than 1
Autumn olive	*Elaeagnus umbellate*	205
Black locust	*Robinia pseudoacacia*	33
Black swallow-wort	*Cynanchum louiseae*	8
Border privet	*Ligustrum obtusifolium*	Less than 1
Brittle waternymph	*Najas minor*	3
Canada thistle	*Cirsium arvense*	47
Greater celandine	*Chelidonium majus*	Less than 1
Climbing nightshade	*Solanum dulcamara*	34
Coltsfoot	*Tussilago farfara*	Less than 1
Common barberry	*Berberis vulgaris*	247
Common buckthorn	*Rhamnus cathartica*	369
Common mullein	*Verbascum thapsus*	Less than 1
Common reed, *Phragmites*	*Phragmites australis*	Less than 1
Creeping buttercup	*Ranunculus repens*	26
Creeping jenny	*Lysimachia nummularia*	Less than 1
Dames rocket	*Hesperis matronalis*	2
European privet	*Ligustrum vulgare*	105
Glossy buckthorn	*Frangula alnus*	456
Ground ivy	*Glechoma hederacea*	1
Japanese barberry	*Berberis thunbergii*	207
Japanese honeysuckle	*Lonicera japonica*	Less than 1
Japanese knotweed	*Polygonum cuspidatum*	7
Japanese wisteria	*Wisteria floribunda*	Less than 1
Leafy spurge	*Euphorbia esula*	16
Morrow's honeysuckle	*Lonicera morrowii*	57
Multiflora rose	*Rosa multiflora*	268
Oriental bittersweet	*Celastrus orbiculata*	237
Purple loosestrife	*Lythrum salicaria*	19
Reed canarygrass	*Phalaris arundinacea*	39
Rugosa rose	*Rosa rugosa*	Less than 1
Sheep sorrel	*Rumex acetosella*	76
Spotted knapweed	*Centaurea maculosa*	2
Winged burning bush	*Euonymus alatus*	Less than 1

Refuge staff released insects to serve as biological agents for purple loosestrife control from 1995 until about 2005 (table 3.14). The refuge used two types of insects in an attempt to reduce that amount of loosestrife on the refuge: *Galerucella* spp. beetles and *Hylobuis transversovittatus* weevils. We have discontinued the biological control program given our poor success due to low beetle and weevil survival and the fact that purple loosestrife occurs in dispersed, low density populations on the refuge.

Table 3.14. Biological Control of Purple Loosestrife on Great Bay Refuge, 1995 to 2003.

Year	Number of *Galerucella* Beetles Released	Number of *Hylobuis* Weevils Released
1995	2,000	1,000
1996	1,000	300
1997	2,000	0
1998	6,000	0
1999	5,000	0
2000	Unknown	500
2001	80	2,000
2002	Unknown	1,000
2003	400	0

Fish and Wildlife

Threatened and Endangered Species

Great Bay Estuary provides habitat for 23 species of State threatened or endangered plants and animals. The refuge hosts several State-listed species including upland sandpiper (endangered) and bald eagle, pied-billed grebe, and common tern (threatened). The State endangered upland sandpiper nests on the adjacent Pease International Tradeport and has recently appeared on the refuge during breeding season. Pied-billed grebes have been reported from Stubbs Pond. Historically, the bay provided habitat for small colonies of common terns, although they tended to experience low productivity. With the success of the tern colony at the Isles of Shoals, the bay's colonies have become less important in the overall picture, although the colony on Hen Island continues to support roughly a dozen pairs.

Osprey populations, a State species of special concern, have been increasing on the bay since the mid-1990s, and in 2006 there were nine known pairs. Not only does the bay host a significant and growing portion of the State's breeding osprey population, it also provides valuable habitat for osprey during spring and fall migration. Statewide, the population is doing well and was recently removed from the State's threatened list.

Birds

The estuary is recognized as a New Hampshire Important Bird Area (IBA). The New Hampshire IBA program began in 2002 as a partnership among New Hampshire Audubon, NHFG, and UNH–Cooperative Extension. Since its inception, the New Hampshire program has identified 17 IBAs throughout the State. The Great Bay IBA was identified based on three criteria (NH Bird Records 2009):

Tim Williams

Great blue heron

1. The presence of threatened and endangered bird species.

2. The presence of other bird species and habitats of conservation concern.

3. The provision of areas where bird species congregate during breeding, migration, or overwintering.

As highlighted above, the Great Bay Estuary and refuge provide habitat for four State-listed bird species. Other bird species of conservation concern in the estuary include the American black duck, salt marsh and Nelson's sparrows, Virginia rail, and least bittern. Major habitats of conservation concern include estuarine habitat, salt marsh, mudflats, and emergent freshwater marsh.

Great Bay Estuary and adjacent habitats provide a major wintering and migration stopover for 20 species of waterfowl, 27 species of shorebirds, and 13 species of wading birds. Over 80 percent of all waterfowl that winter in New Hampshire coastal areas are found in Great Bay. Great Bay is the primary wintering area for black ducks in New Hampshire, with 1,000 to 2,000 ducks usually tallied on the Christmas Bird Count. In contrast, the rest of the State combined supports 500 to 1,000 black ducks. It is also an important wintering area for bald eagles, and a breeding area for osprey. Although it supports much less salt marsh than the New Hampshire coast, the bay's marshes are home to most of the State's populations of Nelson's sparrow. Great Bay Refuge is at the southern edge of the sparrow's global range (*http://iba.audubon.org/iba/viewSiteProfile.do?siteId=2414&navSite=state;* accessed May 2011*)*.

The bay is also one of the primary bald eagle wintering areas in New Hampshire. Eagles use large trees on the refuge, particularly living and dead white and red pines on Woodman Point and Thomas Point, as daytime perch sites or as occasional roost sites. In 2011, a pair of bald eagles nested on the refuge adjacent to the bay, and successfully fledged one chick. The oak-hickory forests and shrub habitats support other many breeding and migrating landbirds of conservation concern.

Breeding bird surveys were conducted intermittently from 1994 to 2008. Table 3.15 below summarizes some of the more common species during June surveys. The species are organized from highest to lowest average relative abundance. Grassland breeding bird surveys have also been conducted. Table 3.16 summarizes the relative abundance of grassland breeding bird species detected during surveys in refuge grasslands between 1999 and 2010. Again, the species are organized from highest to lowest average relative abundance. See appendix A for a complete list of bird species of concern on the refuge.

Table 3.15. Relative Abundance* of Birds Detected During Breeding Bird Surveys on Great Bay Refuge from June 1994 to 2007.

Species	1994	1995	1996	1997	1998	2003	2006	2007	Average
Red eyed vireo	1.50	1.08	1.24	1.00	0.74	1.22	0.64	1.02	1.05
American crow	1.54	1.10	0.74	0.82	0.48	0.20	0.58	0.72	0.77
Blue jay	1.02	0.83	0.52	0.63	0.60	0.78	0.94	0.86	0.77
Common yellowthroat	1.11	0.54	0.80	0.92	0.86	0.53	0.36	0.56	0.71
Black-capped chickadee	0.91	0.69	0.84	1.04	0.38	0.49	0.60	0.40	0.67
Ovenbird	0.78	0.46	0.68	0.53	0.54	0.45	0.76	0.88	0.64
Red-winged blackbird	0.43	0.54	0.40	0.49	0.36	0.59	0.86	1.08	0.60
American goldfinch	0.17	0.63	0.44	0.22	0.30	1.22	0.80	0.82	0.58
Tufted titmouse	0.52	0.52	0.28	0.45	0.32	0.24	0.52	0.40	0.41
Gray catbird	0.50	0.42	0.38	0.47	0.50	0.22	0.34	0.30	0.39
American robin	0.33	0.15	0.46	0.29	0.26	0.43	0.48	0.64	0.38
Eastern wood pewee	0.39	0.35	0.24	0.41	0.34	0.47	0.44	0.28	0.36
Scarlet tanager	0.17	0.52	0.50	0.31	0.26	0.39	0.40	0.34	0.36
Mourning dove	0.35	0.31	0.42	0.37	0.50	0.29	0.32	0.24	0.35
Baltimore oriole	0.26	0.31	0.40	0.24	0.26	0.27	0.40	0.42	0.32
Black and white warbler	0.19	0.39	0.40	0.34	0.28	0.30	0.30	0.34	0.32
Wood thrush	0.35	0.17	0.12	0.22	0.42	0.29	0.60	0.34	0.31
Great crested flycatcher	0.43	0.46	0.34	0.29	0.20	0.45	0.08	0.20	0.30
Song sparrow	0.43	0.27	0.16	0.29	0.28	0.39	0.30	0.26	0.30
Cedar waxwing	0.00	0.33	0.24	0.22	0.28	0.12	0.34	0.54	0.26
Pine warbler	0.33	0.31	0.20	0.29	0.24	0.20	0.24	0.28	0.26
Northern Cardinal	0.39	0.33	0.06	0.22	0.16	0.35	0.24	0.28	0.25
Brown-headed cowbird	0.22	0.38	0.38	0.33	0.08	0.08	0.28	0.16	0.24
European starling	0.11	0.29	0.28	0.16	0.28	0.14	0.22	0.22	0.21

Species	1994	1995	1996	1997	1998	2003	2006	2007	Average
Rose-breasted grosbeak	0.20	0.27	0.12	0.24	0.14	0.29	0.24	0.20	0.21
Black throated green warbler	0.39	0.29	0.24	0.27	0.18	0.10	0.06	0.00	0.19
Eastern kingbird	0.28	0.21	0.16	0.18	0.10	0.20	0.16	0.22	0.19
Eastern towhee	0.24	0.23	0.14	0.20	0.16	0.20	0.16	0.20	0.19
Bobolink	0.17	0.33	0.06	0.06	0.40	0.04	0.20	0.14	0.18
Common grackle	0.04	0.29	0.18	0.02	0.00	0.29	0.40	0.22	0.18
Field sparrow	0.17	0.21	0.12	0.31	0.28	0.18	0.06	0.10	0.18
Yellow warbler	0.24	0.13	0.24	0.24	0.16	0.12	0.08	0.20	0.18
Chestnut sided warbler	0.35	0.25	0.16	0.18	0.14	0.10	0.02	0.02	0.15
Downy woodpecker	0.22	0.17	0.08	0.10	0.32	0.06	0.22	0.06	0.15
Hairy woodpecker	0.04	0.17	0.06	0.12	0.14	0.10	0.22	0.26	0.14
Northern flicker	0.13	0.23	0.20	0.22	0.20	0.08	0.00	0.00	0.13
White-breasted nuthatch	0.00	0.13	0.04	0.14	0.14	0.16	0.26	0.06	0.12
Indigo bunting	0.04	0.08	0.14	0.14	0.04	0.04	0.16	0.14	0.10
Chimney swift	0.00	0.52	0.08	0.00	0.00	0.00	0.00	0.16	0.09
Eastern meadowlark	0.15	0.10	0.04	0.04	0.02	0.06	0.12	0.16	0.09
Eastern phoebe	0.20	0.19	0.08	0.10	0.02	0.02	0.02	0.08	0.09
House finch	0.17	0.33	0.12	0.04	0.04	0.00	0.04	0.00	0.09
Mallard	0.00	0.00	0.00	0.16	0.00	0.04	0.42	0.10	0.09
American black duck	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.60	0.08
American redstart	0.11	0.06	0.08	0.14	0.08	0.10	0.02	0.04	0.08
Killdeer	0.11	0.15	0.06	0.06	0.02	0.04	0.02	0.16	0.08
Barn swallow	0.00	0.13	0.10	0.04	0.00	0.06	0.02	0.18	0.07
Canada goose	0.00	0.00	0.00	0.00	0.00	0.08	0.06	0.42	0.07
Northern mockingbird	0.04	0.02	0.08	0.12	0.14	0.04	0.02	0.00	0.06

Species	1994	1995	1996	1997	1998	2003	2006	2007	Average
Chipping sparrow	0.07	0.00	0.10	0.04	0.02	0.02	0.06	0.10	0.05
Osprey	0.00	0.00	0.00	0.06	0.00	0.04	0.12	0.18	0.05
Tree swallow	0.00	0.10	0.14	0.02	0.02	0.10	0.02	0.00	0.05
Veery	0.07	0.06	0.06	0.02	0.08	0.02	0.00	0.08	0.05
Willow flycatcher	0.02	0.02	0.10	0.12	0.08	0.04	0.02	0.00	0.05
Wild turkey	0.00	0.00	0.00	0.00	0.02	0.02	0.04	0.20	0.04
Black-billed cuckoo	0.00	0.04	0.02	0.04	0.00	0.06	0.04	0.02	0.03
Brown creeper	0.04	0.02	0.04	0.08	0.04	0.00	0.02	0.00	0.03
Brown thrasher	0.07	0.06	0.02	0.02	0.00	0.00	0.04	0.02	0.03
Great blue heron	0.00	0.00	0.00	0.06	0.02	0.06	0.08	0.04	0.03
Prairie warbler	0.04	0.06	0.04	0.04	0.02	0.00	0.02	0.00	0.03
Warbling vireo	0.04	0.04	0.02	0.00	0.02	0.00	0.06	0.02	0.03

** Relative abundance is the average number of birds per species detected per survey point per survey. Only species that are detected consistently from year to year are represented in the table.*

Table 3.16. Relative Abundance* of Grassland Breeding Birds Detected During Surveys Conducted on Grassland Management Units from 1999 to 2010 on Great Bay Refuge.

	Relative Abundance*						
Species	1999	2000	2001	2002	2003	2010	Average
Red-winged blackbird	0.50	1.64	1.50	2.42	1.91	2.43	1.72
Bobolink	0.06	1.68	0.89	1.46	0.87	0.00	1.01
Field sparrow	1.75	0.64	1.00	0.65	0.52	0.57	0.84
Eastern meadowlark	0.00	0.48	0.32	0.50	0.70	0.00	0.40
Upland sandpiper	0.00	0.04	0.11	0.00	0.04	0.00	0.04
American kestrel	0.00	0.04	0.04	0.08	0.00	0.00	0.03
Savannah sparrow	0.19	0.00	0.00	0.00	0.00	0.00	0.02
Vesper sparrow	0.00	0.00	0.04	0.00	0.00	0.00	0.01

** Relative abundance is the average number of birds per species detected per survey point per survey.*

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Lower Peverly Pond looking south

Mammals

Numerous mammals also occur on the refuge. Common species include gray squirrel, shorttail shrew, Eastern cottontail, beaver, red fox, muskrat, and white-tailed deer. The size of the deer population is unknown as they can move freely on and off the refuge. A moose was seen and photographed on the refuge in June 2009. See appendix A for a complete list of mammal species of concern on the refuge.

At least six species of bats occur on the refuge. Great Bay Refuge is within the historical range of the federally endangered Indiana bat and supports suitable habitat; however, this species has no current records from New Hampshire. From 2009 to 2011, the Service hired Biodiversity Research Institute (BRI) to survey for bats at Great Bay Refuge. BRI collected bat capture and echolocation data at the wetland on the Ferry Way Trail. Mist nets and Pettersson ultrasonic detection equipment were used to monitor bat activity in September 2009, July 2010, July 2011, and September 2011. BRI captured multiple bat species in mist nets on the refuge (table 3.17). Migratory species included northern myotis, eastern small-footed bat (State-listed endangered), and little brown bats. Breeding species (lactating females caught) included northern myotis, big brown bat, eastern small-footed bat, and red bat. (Yates and Meattey 2010). Acoustic monitoring also detected hoary bat during migration.

Table 3.17. Bats Detected on Great Bay Refuge in 2009 and 2011.

Common Name	September 2009	July 2010	July 2011	September 2011
	2 nights	3 nights	3 nights	2 nights
Big brown bat	0	10	7	0
Eastern red bat	0	3	1	2
Eastern small-footed bat	4	2	1	1
Hoary bat	0	0	0	0
Little brown bat	1	0	1	0
Northern myotis	10	19	19	9
Unidentified *Myotis* species	0	0	0	2

Conservation focus on bats have been increasing in the past few years due to high population declines for multiple bat species associated with white-nosed

syndrome. In June 2011, the Service completed a 90-day finding on the petition to list the northern myotis and the eastern small-footed bat (76 FR 38095). Their finding concluded that the petition to list these two species presented substantial scientific information indicating that the listing of these species may be warranted. A more detailed 12-month finding on whether or not the listing of these species is warranted is expected to be completed in June 2012. The refuge is also working with a diverse consortium of Federal, State, and academic bat experts and land managers to adapt old military bunkers in the refuge's former Weapons Storage Area to bat hibernacula (see goal 2, objective 2.3 in chapter 4 for more details).

Fish

In the fall of 1992, the Service's Laconia Office of Fishery Assistance conducted a survey of the fish present in three ponds on the refuge. Surveys were conducted on Upper Peverly Pond, Lower Peverly Pond, and Stubbs Pond using an 18.0 foot (5.5 m) boom-type direct current electrofishing boat. This survey was repeated in 2007 (Brown 2008). Generally, the species composition and relative abundance remained consistent between surveys (table 3.18). The following exceptions were observed. A few chain pickerel and rainbow trout were observed in 1992, but not in 2007 in Upper Peverly Pond. American eel and sunfish were more abundant in 2007 than in 1992 in Lower Peverly Pond. American eel, sunfish, and yellow perch were more abundant in Stubbs Pond in 2007 than in 1992. As in 1992, the greatest species diversity was encountered in Stubbs Pond. In 2007, Stubbs was the only pond where chain pickerel, brown bullhead, and golden shiner were captured. Golden shiners were captured in only two small areas in the pond. In all three ponds, there has been a shift toward a greater proportion of larger quality sized largemouth bass in 2007 relative to 1992 (USFWS 1994, 2010). See appendix A for a complete list of fish species of concern on the refuge.

Table 3.18. Fish Species Composition and Abundance in Upper Peverly, Lower Peverly, and Stubbs Ponds in 1992 and 2007.

	Upper Peverly Pond		Lower Peverly Pond		Stubbs Pond	
Species	1992 Survey	2007 Survey	1992 Survey	2007 Survey	1992 Survey	2007 Survey
American eel	F	F	F	M	F	A
Largemouth bass	A	A	A	A	A	A
Sunfish	A	A	F	A	M	A
Alewife	N	N	N	N	N	N
Golden Shiner	N	N	N	N	F	F
Mummichog	N	N	N	N	N	N
Banded Killifish	N	N	N	N	N	N
Chain Pickerel	F	N	N	N	F	F
Brown Bullhead	N	N	N	N	F	F
Yellow Perch	N	N	F	F	M	A
Rainbow Trout	F	N	N	N	N	N
Brook Trout	N	N	N	N	N	N

Note: A = abundant, M = moderate, F = few, N = none

Amphibians and Reptiles

Several surveys and studies have officially documented 15 species of reptiles and amphibians on Great Bay Refuge (table 3.19). Appendix A lists the reptile and amphibian species of concern known, or likely, to occur on the refuge and the Karner blue butterfly conservation easement.

Table 3.19. Amphibians and Reptiles Documented on Great Bay Refuge.

Species	Sighting	Sources*
Frogs and Toads		
American toad	calling, observed	Suomala 1995, 1996; Taylor 1994
Bullfrog	observed	Taylor 1994
Gray tree frog	observed	Taylor 1994
Green frog	observed	Suomala 1995, 1996; Taylor 1994
Leopard frog	observed	Suomala 1995, 1996
Pickerel frog	observed	Taylor 1994
Spring peeper	calling	Suomala 1995, 1996; Taylor 1994
Wood frog	calling, observed	Suomala 1995, 1996; Taylor 1994
Salamanders		
Red-backed salamander	observed	Taylor 1994
Turtles		
Painted turtle	observed, nest found	Suomala 1995, 1996; Taylor 1994
Snapping turtle	observed	Suomala 1995, 1996; Taylor 1994
Snakes		
Common garter snake	observed	Kjoss 1999; Taylor 1994
Northern brown snake	observed	Kjoss 1999
Northern red-bellied snake	observed	Kjoss 1999
Smooth green snake	observed	Kjoss 1999

**Kjoss, V. A. 1999. UNH Masters of Science research study.*

**Suomala, R. Reptiles and amphibians recorded at Great Bay Refuge, 1995 and 1996.*

**Taylor, J. Checklist of amphibians and reptiles for Great Bay Refuge, June 15, 1994.*

Forest Health, Including Forest Pests

The U.S. Forest Service's Durham Field Office assessed the health of Great Bay Refuge's forests in 2006 (Dodds and Cooke 2006). We plan to use the results of their assessment to guide our forest management decisions and address any potential health concerns for the refuge's forests. During their assessment, they first mapped over 61 forested stands on the refuge, which included 10 different

natural community types. They then inventoried and collected the following information in 18 of these stands:

- A general overview of the conditions of forested areas.
- The "health" of overstory trees (e.g., crown condition, growth form, etc.).
- The amount of regeneration occurring in stands.
- The presence/absence of native insects at damaging levels.
- The presence of exotic or invasive species that could threaten the integrity of native ecosystems.

The only potential health concern the assessment found was that many of the forested stands on the refuge are "overstocked." Overall, they found that Great Bay Refuge has a very diverse range of forested habitat given its relatively small size. The refuge also has numerous cavities in both living and dead hardwoods and conifers. These cavities provide important nesting, roosting, and denning sites for wildlife species including birds, mammals, reptiles, and amphibians. They also conducted visual surveys for nonnative insects on inventory plots and on transects through the stands. Although they found no nonnative insects during their 2006 survey, in 2010, the hemlock woolly adelgid was found along McIntyre Road. We will continue to monitor for nonnative insect pests, particularly Asian long-horned beetle, emerald ash borer, and *Sirex noctilio*, which have been found in the Northeast and have caused serious economic and ecological impacts.

The Forest Service also conducts annual aerial surveys to assess forest health condition. In 2007, they mapped 5 acres of tree damage on the refuge, likely related to ice storms. Their 2008 survey detected no damage on the refuge. Their 2009 survey documented discoloration, dieback, and branch breakage on 5 acres of pine plantation located west of the refuge entrance on Merrimack Drive. However, in 2010, the refuge biologist and Dan Sperduto of NHB visited this pine plantation site and found no evidence of a pathogen on the trees. While the native oak-hickory species were germinating in the understory, only the planted Scots pine showed signs of dieback.

Invasive Animals

The mute swan is a Eurasian species that is not native to North America. It was introduced to the U.S. In the late 1800s as a decorative waterfowl for parks, zoos, and private estates. By the early 1900s, small numbers of birds had escaped into the wild, began nesting, and soon established feral populations. Currently, mute swan populations are well established in many states, mainly along the North Atlantic Coast. Populations in the Atlantic Flyway have grown dramatically, from less than 1,000 in the mid-1950s, to more than 14,000 in 2002. Mute swans are highly invasive in wetland habitats, impact native species of fish and wildlife, damage commercial agricultural crops, and pose a threat to human health and safety. Because they consume large quantities of submerged aquatic vegetation and are aggressive, mute swans compete directly with many other waterbird and fish species for critical habitats. Mute swans are highly territorial, and will often vigorously defend nest and brood sites from intrusion by other wildlife, causing serious harm. Some have also attacked humans (Atlantic Flyway Council 2003). The Service continues to work with the NHFG to control this nonnative species within Great Bay Estuary.

Environmental Contaminants

Since Great Bay Refuge is part of the former Pease Air Force Base, the Air Force continues to conduct long-term monitoring of groundwater, surface water, sediment, and fish tissue on the refuge. The original Air Force Base landfill,

operated from 1953 to 1961, is within the boundaries of the refuge lying east of Upper Peverly Pond. According to Air Force Base records, the types of material dumped in this landfill include construction debris, domestic solid waste, and shop waste. The Peverly Brook drainage system receives surface water and sediment from the former landfill, the former Weapons Storage Area, and other dump sites. The primary contaminants from these discharge areas are metals (e.g., aluminum, arsenic, iron, lead, manganese, nickel, and zinc), and pesticides (e.g., DDT-related compounds and lindane) (Department of the Air Force 2001). The levels of DDT in the sediments of the Peverly Brook drainage system, especially Stubbs Pond, may pose a risk to fish. The Air Force believes that it may be safer to leave the contaminated sediments in place, rather than risk re-suspending them in the water while trying to remove them. Currently, the Air Force and the EPA disagree on the need for continued fish sampling (Memorandum from the Air Force to EPA and NH DES dated April 11, 2003). The Pease International Tradeport also continues use urea as a de-icing agent, which may cause elevated levels of nutrients in refuge ponds and the Peverly Brook system (*http://ecos.fws.gov/cap/*; accessed May 2011). Appendix I is a retrospective review of sampling plans and data relating to the clean-up of the Peverly Brook drainage by the Air Force.

Mercury in the blood collected from osprey chicks on the refuge in 2000 was elevated, as compared to other osprey from New England. This is part of a larger trend of elevated mercury levels in wildlife in southeastern New Hampshire, considered a "hotspot" due to prevailing weather patterns (*http://ecos.fws.gov/cap/*; accessed May 2011*)*.

The Service's Northeast Region has conducted studies to determine the extent and magnitude of the "abnormal frog" phenomenon on national wildlife refuges since 1987. At Great Bay Refuge, a team of regional biologists collected data from 1997 to 2005 to assess the level of birth defects in frogs on the refuge. The team compiled their findings in the May 2006 report titled, "Investigation of Contaminant Effects on Frog Development at Great Bay National Wildlife Refuge, Newington, New Hampshire" (Pinkney et al. 2006). Overall, the study found that only a relatively small percentage of frogs on the refuge had birth defects (2 out of 207 wood frogs sampled, or 2.4 percent). However, they did find high rates of mortality for wood frogs in Stubbs Pond, and extended larval periods and high rates (63 percent) of rounded femurs, which can impair hopping ability, in wood frogs in Beaver Pond. Although it appeared that there was some effect of water and sediment contamination on frogs on the refuge, it was not possible to link the observed abnormalities to any specific chemicals. The report is available, upon request, from the Parker River Refuge headquarters.

Cultural and Historic Resources

Historic Structures

The refuge includes three areas that contain historic, or potentially historic, structures:

- The Margeson Estate.
- The 1950s-era Weapon Storage Area.
- The Fabyan Point cabins.

The Margeson Estate is located on Woodman Point in a section of the refuge that is closed to the public. The estate's main house (1894) and caretaker's cottage (circa 1920s) are listed on the National Register of Historic Places (National Register). Since the refuge's establishment in 1992, the main house has remained unoccupied. In 1994 through 1995, a new roof was installed on the main house. It was also tested for hazardous materials (e.g., asbestos and lead paint) in 1994 and

1998. From 1992 to 2002, the refuge used the caretaker's cottage for housing. In 1994 through 1995, the cottage's exterior was painted and new roof was installed. 1998, it was tested for lead paint and in 1999, the window sashes on its first story were replaced.

The Margeson Estate's main house is in poor condition due to deterioration that has taken place over at least the past three decades, with extensive moisture damage to the structure and finishes that occurred prior to the roof replacement. There is also pervasive mold throughout the building. The caretaker's cottage is in good condition, but also has pervasive mold. Both buildings are uninhabitable in their current condition. The refuge does not have a potential use for either building.

The former Weapons Storage Area is located east of the existing refuge visitor headquarters. It is surrounded by a fence and is also closed to the public. The area was used by the Air Force as a highly secure site for storing and maintaining various types of munitions (e.g., small arms ammunition) and weapons systems (e.g., conventional and nonconventional missiles and bombs). In developing the area, the Air Force heavily manipulated the site. They constructed drainage ditches throughout the area to try to improve drainage around their structures. Based on 1952 aerial photos, it does not appear that natural wetlands were present on the site prior to their construction of the Weapons Storage Area. When it was in use, the area covered 50 acres and was surrounded by an 8-foot high chain link fencing topped with barbed wire. Facilities within the area included 15 earth-covered storage bunkers and various nondescript one-story concrete-block storage, support, and administrative buildings. The barrel-vaulted bunkers are made from reinforced concrete and are covered with about 2 feet of soil and vegetation. Two of the bunkers were built for storage of capsules for early nuclear weapon designs. Each bunker has several ventilation holes and two, large steel doors at the front.

Former Weapons Storage Area

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Since acquiring the refuge in 1992, we have removed five buildings, the razor wire off the perimeter fence, and over 100 telephone and light poles from the Weapons Storage Area. We have also been removing and recycling metal from the bunkers and other buildings. We had asbestos removed from the concrete block buildings between 2008 and 2009, which structurally altered the buildings. Our intent is to remove the remaining concrete block structures, water tower, and adjacent roads and fencing, as resources allow. As structures are removed, we will restore the disturbed areas to native habitat. Currently, we are using some of the bunkers for storage. We are also evaluating the potential to use some of the bunkers as hibernacula for roosting bats. We do not anticipate removing the bunkers because of the high estimated cost for their removal, their usefulness as storage spaces, and their potential as bat roosting habitat.

The third area that contains potentially historic structures is Fabyan Point, a peninsula at the end of Fabyan Point Road in a section of the refuge that is closed to the public. Fabyan Point has a complex of six small cabins along the Great Bay shoreline. Two cabins appear to date to the 1920s (one wood-framed and one concrete block), while the remaining four cabins date to circa 1947 (all wood-framed). Prior to the refuge's acquisition of Fabyan Point in 2003, the area was private property. By this time, the five wood-framed cabins were in poor condition. They are supported by concrete block piers that rest directly on the ground and which have heaved over the years, affecting the structure of the buildings. The buildings also suffer from pervasive mold and moisture damage. The concrete block cabin is in good condition, but also has pervasive mold. None of the buildings are inhabitable and the refuge does not have a potential use for any of the buildings. The cabins have also become a target of vandals and squatters.

Archaeological Resources

In December 1988, the Pease Air Force Base was selected as one of the 86 military installations to be closed as part of the Secretary of Defense's Commission on Base Realignment and Closure (BRAC). Archaeological resources in the refuge are mostly known from two 1991 surveys done as part of the BRAC process and from a 1999 to 2000 study undertaken for the town of Newington and funded by a certified local government planning grant. Results of both have recently been incorporated into an archaeological overview produced as part of the CCP process (Public Archaeology Laboratory, Inc. 2010).

Only one pre-Contact archaeological site has been identified on the refuge. However, in light of proximity to maritime resources of the bay, as well as freshwater and upland resources, other unrecorded sites of that period are very likely to be present. Fifteen Euro-American sites are recorded within the refuge. Those include the landing for a 17th century ferry to Durham, a 19th century brickyard, and a number of late 17th to 20th century farmsteads. Burials in four small cemeteries were exhumed and reburied off-refuge when the Air Force Base was constructed. It is possible that some unmarked graves were not discovered and removed. None of the cemetery locations have surface evidence today. While it is likely that all sites dating from the 18th century and later within the refuge have been identified, it is possible that additional 17th century sites exist, as those tend to be less visible on both the landscape and historic period maps. The city of Portsmouth purchased land and water rights to Peverly Brook and its tributary streams in 1900. The brook was dammed in two places and by 1903 water was being pumped to the city's public water supply. That water system was discontinued when the Air Force acquired the lands in the 1940s (Rowe 1987). The Weapons Storage Area and a considerable area in the northeast part of the refuge were both heavily disturbed by airbase construction. In 1962, the Air Force constructed Stubbs Pond impoundment. Most of the remaining refuge land was unaffected by airbase construction and use.

Public Use Programs

As an unstaffed refuge, Great Bay Refuge has had limited ability to conduct a visitor services program. Despite these limitations, the refuge is popular, especially for birders and walkers. The estimated annual visitation is approximately 30,000 visitors.

The Peverly Pond Trail (described below) is wheelchair accessible, as are the restrooms and refuge headquarters. The refuge is open from dawn to dusk, with vehicle access controlled by a timed gate along Arboretum Drive. The trails are for foot traffic only. Bicycles and motor vehicles are limited to the entrance road and parking lot. Pets are not permitted on the refuge. All other areas beyond the parking lot and the two trails are closed to the public.

Trails

Two nature trails are accessible from the visitor parking lot at the end of Merrimack Drive, adjacent to the refuge headquarters building (map 3.2).

Ferry Way Trail
The 2-mile Ferry Way Trail begins at the northwestern edge of the parking lot. It starts out as an asphalt path next to a chain link fence along the former Weapons Storage Area. After following the fence line, the trail crosses a woods road and swings left onto another old woods road. The trail passes through woods and fields, by wetlands and an apple orchard, loops down to Great Bay, then backtracks to the parking lot. A leisurely walk on this moderately difficult trail takes about 2 hours.

Peverly Pond Trail
The 0.5-mile Peverly Pond Trail begins to the east of the parking lot. This loop trail winds though an oak-pine forest, follows a portion of shoreline along Upper Peverly Pond, and passes several vernal pools. A photography blind in located along the trail and offers views of Upper Peverly Pond. A leisurely walk on this easy trail takes about 30 minutes. The trail is fully accessible.

Fishing

Various military activities on the former Pease Air Force Base resulted in, or contributed to, contamination of sediments, water, and fish on what are now refuge lands. Over the last 10 to 15 years, studies and monitoring shows that while some contaminant issues are improving, other concerns still exist. In particular, we are concerned about contamination in the Peverly Brook drainage and the refuge's three impoundments. We are currently uncertain about the impact of this contamination on fish health and water quality, and the risks to humans from handling or consumption. Due to these concerns, the refuge is closed to fishing.

Hunting

History
Prior to Service ownership, deer and waterfowl hunting were permitted by the Air Force, but it was limited to military personnel, retirees, and dependents, and only in certain areas. From 1967 to 1989, the Air Force used hunting as a management tool, due to the need to minimize aircraft strikes on the runway. It was estimated that 8 to 10 deer were taken annually from throughout the former Pease Air Force Base. The Air Force also permitted waterfowl hunting only on Stubbs Pond and only for Air Force personnel, dependents, and retirees. The former base was closed to hunting from 1989 to 1993 in advance of the land transfer to the Service (USFWS 1995). Currently, the only types of hunting allowed on the refuge are white-tailed deer and waterfowl hunting are permitted on the refuge, as stipulated in 50 CFR, Part 32, Subsection B, § 32.48.

White-tailed Deer Hunting
When the refuge was first proposed, the Service received a range of public comments on deer hunting. Some thought the hunt should continue, while others thought hunting should only occur as a biological management tool. A Hunt Plan was completed for Great Bay Refuge in 1993 (USFWS 1993). In 1995 the Service completed an EA for establishing and conducting an annual, public white-tailed deer hunting program and waterfowl hunting program on the refuge. The determination from this assessment was to open the refuge to controlled hunting of white-tailed deer and waterfowl in accordance with all Federal, State, and local regulations (USFWS 1995).

The first white-tailed deer hunt on the refuge occurred in the fall of 1996 and has been held every year since then. The hunt is a 2-day, Saturday to Sunday hunt, by permit only. A maximum of 20 permits per day are drawn from a pool of applicants each year. From 1996 to 2007 the number of hunters has ranged from

13 to 22. The number of deer harvested during a given hunt has ranged from 8 to 22 deer, with a mix of does and bucks taken.

Waterfowl Hunting
The 1995 hunting EA also provided for a waterfowl hunt program on the refuge. Waterfowl hunting is currently allowed along the shoreline of the refuge up to posted refuge boundary signs. Waterfowl hunters are only allowed access to the refuge by boats launched from off-refuge locations; overland access through the refuge is prohibited. The 1995 EA allowed for additional restrictions if needed, including limiting the number of waterfowl hunters. Currently, the number of waterfowl hunters at the refuge is so low (less than 3 people per season), restrictions on numbers of hunters have not been necessary. Other sites around Great Bay provide more extensive waterfowl hunting opportunities and see more use.

Volunteer Program

Volunteers are particularly vital at Great Bay Refuge, given the lack of Service staff. The Wednesday Volunteer Group is the biggest group on the refuge that works most of the year except winters. Their projects are many and varied. They have been salvaging scrap metal to be recycled from the Fabyan Point cabins and former military buildings on the refuge. They also maintain trails, mow grassland habitat, assist with waterfowl banding, maintain and repair equipment, monitor the fish ladder and fish activity, tend the native garden outside of the headquarters, conduct invasive species inventories and control, and conduct osprey surveys. For the past three summers, a volunteer couple has been living and working on the refuge. They have helped tend the gardens, perform light maintenance, and provide other assistance as needed. The Service has also engaged volunteers through other programs, such as Phillips-Exeter Academy classes. Volunteers contribute approximately 2,500 to 3,000 hours on the refuge each year. The refuge does not currently have an active Friends Group.

Key Refuge Partnerships

Great Bay Resource Protection Partnership
The GBRPP is a coalition of public and private conservation groups that formed in 1994 to help protect the remaining critical habitats within and around Great Bay. The GBRPP takes a comprehensive, landscape-scale approach to conservation and habitat protection by developing and implementing conservation strategies through a combination of scientific field studies and ongoing communication with local, regional, State, and national conservation representatives. So far, the partnership has been very successful in their land protection efforts.

The Partnership's primary activities include the following:

- ***Conservation Planning:*** The Partnership conducts habitat analysis studies to identify significant habitat areas to be considered for protection.
- ***Land Conservation:*** Based on the conservation planning field work, the Partnership seeks to protect large blocks of significant conservation land through working voluntarily with landowners on the purchase or donation of land or conservation easements.
- ***Stewardship:*** Partner organizations collaborate on stewardship activities such as restoration, resource management, and public access on protected lands.
- ***Education and Outreach*****:** Partner representatives provide technical assistance to communities, conservation entities, and landowners.

The principle partners, which meet quarterly in the GBRPP, are Ducks Unlimited, Inc., GBNERR, New Hampshire Audubon Society, NHFG, SPNHF,

TNC–New Hampshire Chapter (lead partner), the EPA, the Service, the refuge, and the USDA–Natural Resources Conservation Service. The partnership works closely with several regional land trusts and conservation districts including the Southeast Land Trust of New Hampshire, Bear Paw Regional Greenways, Rockingham County Conservation District, Strafford Rivers Conservancy, and Strafford County Conservation District (*http://www.greatbaypartnership.org/*; accessed May 2011*)*.

New Hampshire Coastal Watershed Invasive Plant Partnership
Great Bay Refuge, represented by the refuge manager, is a "Sustaining Partner" of the New Hampshire Coastal Watershed Invasive Plant Partnership (CWIPP). This partnership among 11 agencies and organizations concerned with invasive species was formed in 2008. The principal partners signed an agreement and created a framework of cooperation to address the effects of noxious and invasive plants across jurisdictional boundaries. The signatories agreed that it was to their mutual benefit and in their mutual interest to work cooperatively to inventory, monitor, control, and prevent the spread of invasive plants across jurisdictional boundaries within New Hampshire's coastal watershed. The goal through this cooperative effort is to achieve better management of invasive plants while improving working relationships between the signatories and the public. Although sustaining partners are not signatories to the agreement, they, including Great Bay Refuge, have significant interests in the success of the partnership (*http://des.nh.gov/organization/divisions/water/wmb/coastal/cwipp/index.htm;* accessed May 2011*)*.

Law Enforcement
Great Bay Refuge is situated at the end of a long dead-end road. The entrance is controlled by a timed gate that opens at dawn and closes at dusk. The lack of refuge staff stationed at Great Bay Refuge and the refuge's relatively isolated location creates some law enforcement concerns. A refuge law enforcement officer is based out of the Parker River Refuge office, and serves both Great Bay and Wapack Refuges. In addition, a refuge law enforcement zone officer for this region is located at Mississquoi Refuge in northwestern Vermont. Given the shortage of law enforcement capacity, Great Bay Refuge maintains a critical partnership with the town of Newington Police Department.

Pease Development Authority Wildlife/Bird Air Strike Hazard Committee
In 1992 a Memorandum of Agreement (MOA) was signed between the Service, the Federal Aviation Administration (FAA), the U.S. Department of Agriculture–Animal and Plant Health Inspection Service, and PDA. The MOA calls for coordination and quarterly meetings among the parties. Meetings are designed to review and discuss past and future wildlife management practices by the Service and PDA on the refuge and the airport facility, respectively, discuss the effects of such management practices on airport operations and on Service trust resources, and discuss airport facility aircraft operations and their potential effects on the refuge (MOA 1992). The group of representatives is referred to as the Wildlife/Bird Air Strike Hazard Committee.

Karner Blue Butterfly Conservation Easement

Great Bay Refuge also includes a 29-acre conservation easement, comprised of pine barrens habitat, in Concord, New Hampshire (map 1.2). The property is managed primarily for the federally endangered Karner blue butterfly. The conservation easement is approximately 45 miles west of Great Bay Refuge. The parcel abuts the Concord Airport and is within a fragmented, but important complex of remnant pine barrens habitat that supports rare moths and butterflies. The conservation easement land is a mix of open pitch pine-scrub oak, pine-hardwood, and other scrubland. Although not the focus of our management, the conservation easement's habitat also supports several State-listed species and State species of concern, including hognose snake, black racer, and grasshopper

Karner blue butterfly displaying upperside (right) and underside (far right) coloring

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sparrow. Additionally, table A.2 in appendix A list all of the species in greatest need of conservation that are potentially present on the conservation easement and throughout the Concord Pine Barrens.

This conservation easement was established in July 1992 through a cooperative agreement between the Service, the city of Concord, the CCDC, the U.S. Postal Service, and TNC. The conservation easement lies in the Concord Airport Industrial Park and consists of two adjacent parcels on which easements were donated to the Service by the city of Concord following an exchange of airport land between the city of Concord and the non-profit CCDC. TNC agreed to serve as a managing partner with the Service while the city of Concord and CCDC agreed to cooperate in the research and management of Karner butterfly habitat in management agreement areas.

Since 2008, Great Bay Refuge and the conservation easement have been administered by Parker River Refuge staff based in Newburyport, Massachusetts. There are no refuge buildings on the conservation easement and the property is closed to hunting. There is an unpaved right-of-way road, oriented east-west, that bisects the conservation easement. There are gates at the entrance and the exit of the property to preclude vehicle access. This unpaved road serves as an approximately 0.4-mile wildlife observation trail and is open to pedestrian access only. An informational kiosk located at the west entrance explains management for Karner blue butterflies.

From 1992 to 1999, TNC carried out most of the management on the conservation easement, which included removal of unwanted vegetation by mechanical methods and planting of wild lupine. In 1999, the Service conducted vegetation removal and a prescribed burn.

Since 2000, NHFG has conducted the onsite management which has continued with vegetation removal, herbicide applications, prescribed burning, plantings, moth and butterfly surveys, and a captive rearing program. NHFG received funding for some of their management activities on the conservation easement through a MOA with the New Hampshire Army National Guard (National Guard). This MOA, which was active through 2011, facilitated the transfer of funds from National Guard to NHFG support habitat restoration and monitoring activities, including prescribed burning, mowing, and forestry operations, in addition to mark-recapture surveys on the Karner blue butterfly and frosted elfin butterfly, vegetation plots, lupine populations, and presence or absence of other Lepidoptera. These funds were provided as mitigation for a helicopter hanger the National Guard built in an area identified as habitat for the federally endangered Karner blue butterfly.

Table 3.20 presents a brief outline of NHFG's habitat management on the conservation easement from 2000 to 2011. Table 3.20 includes the results of the captive rearing program and population monitoring data.

Table 3.20. New Hampshire Fish and Game Management Activities at the Concord Pine Barrens from 2000 to 2011.

Management Action	Total
Prescribed Burning	6 acres
Vegetation Removal	10 acres
Herbicide	3 acres
Planting of Seedlings	over 5, 500 seedlings
Planting of Seeds	over 6, 000 grams of seed

Table 3.21. Captive Rearing of Karner Blue Butterflies for Release onto the Service's Concord Pine Barrens Conservation Easement.

Year	Brood	Number of Adults[1]	Number of Wild Adults Marked[2]	Number of Adults Recaptured[3]
2000	1	0	–	–
2000	2	0	–	–
2001	1	44	–	–
2001	2	5	–	–
2002	1	193	–	–
2002	2	102	–	–
2003	1	203	–	–
2003	2	176	–	–
2004	1	337	–	–
2004	2	1,231	31	167
2005	1	607	39	160
2005	2	1,177	149	347
2006	1	1,138	21	149
2006	2	348	49	45
2007	1	505	20	49
2007	2	968	54	301
2008	1	271	58	65
2008	2	2,136	64	404
2009	1	1,017	87	316
2009	2	3,798	260	1,006

Year	Brood	Number of Adults[1]	Number of Wild Adults Marked[2]	Number of Adults Recaptured[3]
2010	1	194	320	245
2010	2	2,609	278	394
2011	1	22	58	29
2011	2	742	90	283

[1] *Total adults enclosed in captive rearing laboratory for either breeding or release in New Hampshire and New York.*

[2] *Number of unmarked adult butterflies observed during mark recapture surveys.*

[3] *Number of marked adults observed during mark recapture surveys, including adults released from captive rearing laboratory.*

Additional Partnerships

There are several other crucial ongoing partnerships related to the conservation easement and its management.

Concord Municipal Airport Development and Conservation Management Agreement.
Participants in this agreement include the city of Concord, NHFG, the Service, New Hampshire Department of Resources and Economic Development, National Guard, and New Hampshire Department of Transportation–Division of Aeronautics. This agreement was executed in November 2000 for the purpose of managing airport lands adjacent to the Service conservation easement in a manner that provides and enhances essential habitat for federally listed and State-listed threatened and endangered butterfly and moth species, such as the Karner blue butterfly. The agreement serves as the city's compensation to offset the loss of species and habitat in the designated development zones.

Kids for Karners
This program was started by the National Wildlife Federation and NHFG around 2000. Over the past 11 years, over 2,500 lupine and nectar plants have been grown by local school children and planted on the Service's conservation easement land. The project includes a teachers training in the winter, classroom plantings in the spring, and a field trip to the conservation easement at the end of the school year to plant lupine and tour the Concord Pine Barrens.